COLLECTION AND EVALUATION OF FIELD DATA AROUND EXCAVATIONS IN POTASH TO EVALUATE EXCAVATION PERFORMANCE OR CONCEPTS FOR NEW MINING LAYOUTS.

FINAL REPORT

BY

COMINCO LTD.

Work on this project was conducted under the auspices of the Canada Centre for Mineral and Energy Technology, Energy, Mines and Resources, Canada.

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Executive Summary

The work described in this report was carried out by Cominco Ltd. Potash Operations under D.S.S. contract number OSQ83-00320, project number 310104.

A five room entry system was cut in potash at a depth of approximately 1100M over a period from January to June 1984. As the system is symetrical the east half was intensively instrumented to monitor accumulative room closure, internal pillar, back and floor and abutment deformations, and stress levels.

A level survey was implemented in an effort to determine the proportion of the total vertical closure contributed by the back subsiding.

Total horizontal and vertical cumulative closure and rate graphs are produced.

The abutment wall rock was instrumented to a depth of 200 ft. (61M). Deformations were noted to 75 ft. (23M).

Yield pillars were instrumented throughout their total width. Excellent strain distribution patterns and total expansion records were obtained. The back of the centre and adjacent access rooms were instrumented to 30 ft. (9M). Comparison of expansion rates showed somewhat increased expansion above the wider centre room.

The floors of these rooms were instrumented to 100 ft. (30.5M). Problems with these extensometers throughout the project resulted in poor records of floor deformations. Revised reading methods appear to be providing reasonable results, however these sites are to be replaced.

Pressure cells provided by the Saskatchewan Research Council were installed at various depths to 30 ft. (9M) into the back, 100 ft. (30.5M) into the floor, in the yield pillars and to 100 ft. (30.5M) into the abutment. Although several cells failed at various times throughout the project period results are considered to be of significance, in particular, the outlining of a higher stress concentration approximately 20 ft. (6M) above and 50 ft. (15M) below the centre of the entry system.

Level surveys from the shaft to the project site were carried out first in July, 1984, then in October, 1984 and February, 1985. Results indicate an average of 21 percent of the total room closure is contributed by roof subsidence.

Introduction

This report covers the work carried out by Cominco Ltd. Potash Operations from March 14, 1984 to March 31, 1985 under D.S.S. contract number OSQ83-00320, Project Number 310104. The scientific authority was Dr. G. Herget of Canmet.

The study was carried out in a five room entry system situated 1600M from any previous extraction. The data collected is therefore considered to be characteristic of openings in virgin ground conditions. Data collected includes total vertical and horizontal room closure, internal creep deformations, and stress measurements.

Technical Discussion

The five entry system, at a depth of approximately 1100M, consists of four 5.5M wide by 3.35M high rooms and a centre room 7M wide. This centre room was cut 5.5M wide on May 25, 1984 and widened to 7M on June 4, 1984. The rooms are separated by nominal 6.7M yield pillars. The roof and floor beds of the outer rooms, (2101 and 2015) which are cut first, relax and separate thus protecting the inner rooms from damaging horizontal stresses. This separation necessitated cutting a vertical slot 15cm wide by approximately 3M deep in the back of 2105 to relieve the horizontal loading and provide a stable work area for installing instrumentation. The entry system configuration and completion dates at the project site are shown in figure 1.

A drum recorder was installed immediately behind the miner rotors approximately 1M from the face in an attempt at obtaining as complete a vertical closure history as possible. This could only be accomplished for sites immediately adjacent to the walls. (rib sites)

Borehole extensometers were installed at depths of 5, 10, 20, 25 and 30 ft. (1.5, 3, 6, 7.6 and 9M) in the back and 10, 25, 50, 75 and 100 ft. (3, 7.6, 15, 22.8 and 30.5M) in the floor of 2103 and 2104.

Yield pillars were instrumented with similar extensometers with anchors located appropriate to the pillar width. These were usually at depths of 5, 10, 15 and 21.5 ft. (1.5, 3, 4.6 and 6.5M). Details of each site are provided on the graphs.

The infinite wall (East Wall - 2105) was instrumented at depths of 25, 50, 75, 100 and 200 ft. (7.6, 15.2, 22.8, 30.5 and 61M).

Hydraulic pressure cells supplied by the Saskatchewan Research Council were installed at depths generally corresponding to extensometer depths. Cells in vertical holes were non-directional, that is, cells which responded to loads from all horizontal directions. Cells in horizontal holes were flat jack cells oriented to respond to vertical loading. Both cells are essentially infinitely soft inclusions and should, with time establish equilibrium with the absolute stress.

An important part of the project was to initiate a level survey from a reference point established on the shaft concrete lining out approximately four kilometers to the project site.

The survey was carried out three times during the contract period.

1. Creep Monitoring

1.1 Room Closure

Figure 2 shows the closure history of rooms 2103, 2104 and 2105. The reloading effects of each subsequent room can readily be seen.

While cutting 2102, an increase in closure of .6 cm was observed over a three day period in 2104, located 20M away. This can be seen starting at day 128 on the 2104 closure curve in figure 2. When cutting 2103, only 6.7M away an increase of 2.1 cm was observed over a three day period. This starts at approximately day 145 in figure 2.

Figure 3 shows closure data from 2105. Note the separation between centre-line and rib sites. Readings were discontinued due to unsafe conditions.

Figure 4 shows the vertical closure in 2104. Note the much smaller difference between the centre-line and rib sites, indicating the protection provided by using stress relief techniques.

The reloading due to cutting 2103 is very evident.

The closure in 2103, the centre drift, is shown in figure 5. The similarity between centre-line and rib sites is even more evident.

The vertical closure rate reduction curves on log log scale are shown in figures 6, 7 and 8. Again note the difference between centre-line and rib rates in 2105. The centre-line is closing more than twice as fast as the ribs indicating separation in the roof and floor beds.

The agreement between sites at other locations (300, 500, 700M) and the project site seen in figures 7 and 8 gives confidence that the project site is providing data characteristic of the entry.

Horizontal closure of these rooms is shown in figures 9, 10 and 11. The closure in 2105 (figure 9) was not initiated until after completion of 2103. The estimate of approximately 12 inches (30 cm) is based on the difference between the first readings at 130 days and the first reading noted in similar 5.5M wide rooms at an age of .5 days. This was not possible in 2103 (figure 11) as the second pass to 7M does not produce a standard room width.

Horizontal closure rates are shown in figures 12, 13, 14 and 15. The response to cutting subsequent rooms is evident. Again note the project site agrees with other sites throughout the entry system.

1.2 Internal Deformations

Figure 16 and 17 show the expansion observed to 30 ft. (9.1M) in the back of 2104 and 2103. The age scale corresponds to the date of room completion.

Figure 18 compares the zone creep or strain rates in 2103 and 2104. That is the rate per foot noted in the zones 0 - 5 ft., 5 - 10 ft., 10 - 20 ft., 20 - 25 ft., and 25 - 30 ft. Note continued expansion from 25 to 30 ft. (7.6 - 9.1M) above the wider 2103 drift. The compression from 25 - 30 ft. in 2104 has been evident from an age of approximately 200 days and can also be seen in figure 16.

Continued reduction in creep rates is shown on log log scale in figure 19. Rates in the wider 2103 are not reducing as quickly as in the narrower 2104.

The total expansion of the infinite east wall of 2105 (abutment) is shown in figure 20. A slight compression is noted from 75 to 100 ft. (23 - 30.5M) and from 100 to 200 ft. (30.5 - 61M). Although considered to be due to the accuracy of readings or a problem with the long length of rods, it has been continuous.

However, after 400 days and 4 inches (10 cm) movement, the 100 ft and 200 ft. (30.5 and 61M) rods were within .010 inches of each other. The reduction in creep rates is shown on log log scale in figure 21. Figure 22 shows the zone creep rates versus depth.

Expansion of the pillar between 2104 and 2105 is shown in figures 23 and 24. Day 0 is April 30/84, the date 2104 was completed. Site 1 was installed 4 days after the first pass in 2103 was cut and the high, early expansion reflects the reloading. The jump in deformation observed after day 35 corresponds to widening the second pass in 2103 on June 4/84. These effects are not observed at site 2 which was installed on June 12/84.

Figure 25 shows deformations observed in the yield pillar between 2103 and 2104. Day 0 is June 4/84 corresponding with the completion of 2103.

A comparison of the creep distribution patterns in these pillars is shown in figure 26. Note the deformation centre in the west pillar (2103 - 2104) coincides with the pillar centre-line. The deformation centre in the east pillar (2104 - 2105) is skewed towards 2104. We have found this to be typical of pillars adjacent to relief drifts (2105) and is a function of the loss of confinement to the top and bottom of the pillar resulting from failure of the immediate roof and floor beds in the relief drift.

Figure 27 compares sites 1 and 2 again displaying the skewness.

Floor extensometers have given problems since installation. Readings were erratic and never approached any significant proportion of the total room closure. It was hoped that given time, the ground movements would overcome any resistance of the rods, but this has not been the case. A method of tensioning the rods was adopted during the latter stages of the project and now appears to be providing reasonable results. From December 3/84 to March 1/85 the total room closure in 2104 was .82 inches (20.8 mm). Of that .048 inches (1.219 mm) was contributed by the first 30 ft. (9.1M) of back.

Floor movements to 100 ft. (30.5M) provided .730 inches (18.54 mm), of which .715 inches (18.18 mm) occurred in the first 10 ft. (3M) and .727 inches (18.46 mm) in 75 ft. (22.8M).

The total contributed by the instrumented portions of the back and floor amounted to .772 inches (19.6 mm) or 94 percent of the total room closure.

The .042 inches (1.06 mm) unaccounted for occurred above 30 ft. (9.1M) into the back and/or below 100 ft. (30.5M) into the floor.

2. Stress Measurement

The ages displayed on the graphs are the ages since cell installation.

Figure 28 shows results from a cell oriented to monitor vertical stress in the pillar between 2104 and 2105. Day 0 is May 17/84. 2104 was 17 days old. The sharp rise starting on day 8 corresponds to cutting the first pass of 2103 on May 25/84. The second jump on day 18 corresponds to cutting the second pass on June 4/84.

Figure 29 shows results from cells in the infinite east wall abutment of 2105. Day 0 is June 1/84. Cells had been installed at 75 and 100 ft. (23 and 30.5M), however these failed very early. The cell at 45 ft. (13.7M) appears to have failed at approximatelly 190 days.

Figure 30 compares results from the cell in figure 28 and the cell at 10 ft. (3M) in figure 29. Results appear to indicate a transfer of load from the yield pillar to the adjacent abutment.

Figure 31 shows results from a cell installed in the floor of 2105. Day 0 was May 18/84, just prior to completing 2103.

Figure 32 shows results from the yield pillar between 2103 and 2104. Day 0 is June 21 making the pillar 17 days old at the time of installation. The cell at 11 ft. (3.35M) failed very early. This cell is to be replaced with a cell which is also instrumented with strain guages to monitor the effect of tensions created by horizontal pillar strains.

The 8 ft. (2.4M) cell guage panel was damaged by heavy equipment. This cell apears to be responding since rehabilitation.

Figure 33 shows results from the back of 2104. Day 0 is June 21/84, 17 days after completing 2103 and 52 days after completing 2104. Of particular interest is the response noted at day 154. The immediate back of 2105 had been slotted in March/84 to a depth of 10 ft. (3M) in order to prevent early failure and provide a safe work area for installing instrumentation. With time, the slot closed and required recutting. This was done in early December and resulted in an immediate increase in the pressures observed on the 20 and 30 ft. (6 and 9M) cells, and a somewhat delayed drop in the pressure observed on the 10 ft. (3M) cell.

The pressure distribution patterns observed on days 165, 168 and 249 are shown in figure 34.

Cells installed in the back of 2103 are shown in figure 35. Day 0 is July 13 making the room 39 days old. The 30 ft. (9M) cell failed almost immediately but appears to be responding since rehabilitation.

A comparison of figure 33 from 2104 and figure 35 from 2103 shows the pressures noted on the 10 ft. (3M) cells are identical in both rooms, however the pressures on the 20 and 30 ft. (6 and 9M) cells are much higher in 2103, particularly prior to recutting the slot in 2105.

Figure 36 shows results from the floor in 2103. Day 0 is again July 13/84. Currently it is not known whether or not the drop in pressure after day 60 is real or a problem with the cells, therefore results only up to day 30 have been used for comparisons. The pressure distribution on day 28 (Aug. 10/84) is shown in figure 37.

Similar plots of results from 2104 are shown in figures 38 and 39. Day 0 is July 3/84. The distribution plot is of day 52 (Aug. 24/84). Comparing pressures between the two rooms again shows higher levels below 2103 than below 2104, particularly at a depth of 50 ft. (15M).

In general, results show a higher stress concentration occurring 20 ft. (6M) above and approximately 50 ft. (15M) below the central room.

3. Level Survey

Movements in the immediate back, to date, have been very small in relation to the accuracy obtainable in such a long survey. Any comparison with extensometer results will be questionable. With time the total ground movements will become significantly greater than the possible survey error and results will become more meaningful.

However, these preliminary results are quite encouraging and reasonable when compared to the total room closure.

From July/84 to Oct./84 the level survey indicated a decrease in back elevation at the project site of 10.0 mm. The total room closure over this period was 45.46 mm. The contribution of the back to the total closure was therefore 21.9 percent.

From July/84 to Feb./85 the level survey indicated a 14.8 mm drop in back elevation. The total room closure over the period was 74.29 mm., of which 19.9 percent was due to the back.

4. Conclusions and Recommendations

Cominco plans to continue the level surveys and monitoring the project site. The additional information can be made available to individuals at the discretion of the company.

It is felt that the percent room closure due to the roof and floor will be dependent upon the location of the openings within the evaporite and the proximity to the overlying Dawson Bay limestone. A second level approximately 100 ft. (30.5M) below the current mining level will be instrumented to determine the contribution of the roof and floor in an area with substantially increased salt cover. This information will be added to this report.

When reviewing the data, particularily the pressure cell program, one can see where additional information would be of value. It is recommended that this project continue to fill in the gaps, and that portions be duplicated to confirm findings to date.

At the time of installation, the hydraulic cells are generally pressured to 1500 - 2000 psi. (10.3 - 13.8 MPa). After an initial drop, the pressure increases similar to a creep curve and normally reaches a constant level after 30 to 60 days. Cells at the project site were installed when the entry system was quite young. Stresses around the system were in a dynamic state and although cells may not appear to stabilize, I suggest that they did reach equilibrium with the ground and displayed very real changes taking place during the early life of the entry.

This project has made available real field data which will no doubt be invaluable to outside researchers who do not always have access to a mine. Very little interpretation has been made in order to allow others to reach independent conclusions.

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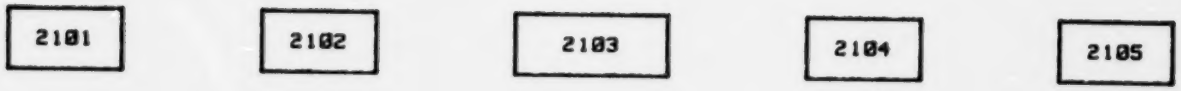
/drb

CONVERSION TABLE

1 Inch = 2.54 cm. = .0254 M.
1 Foot = 30.48 cm. = .3048 M.

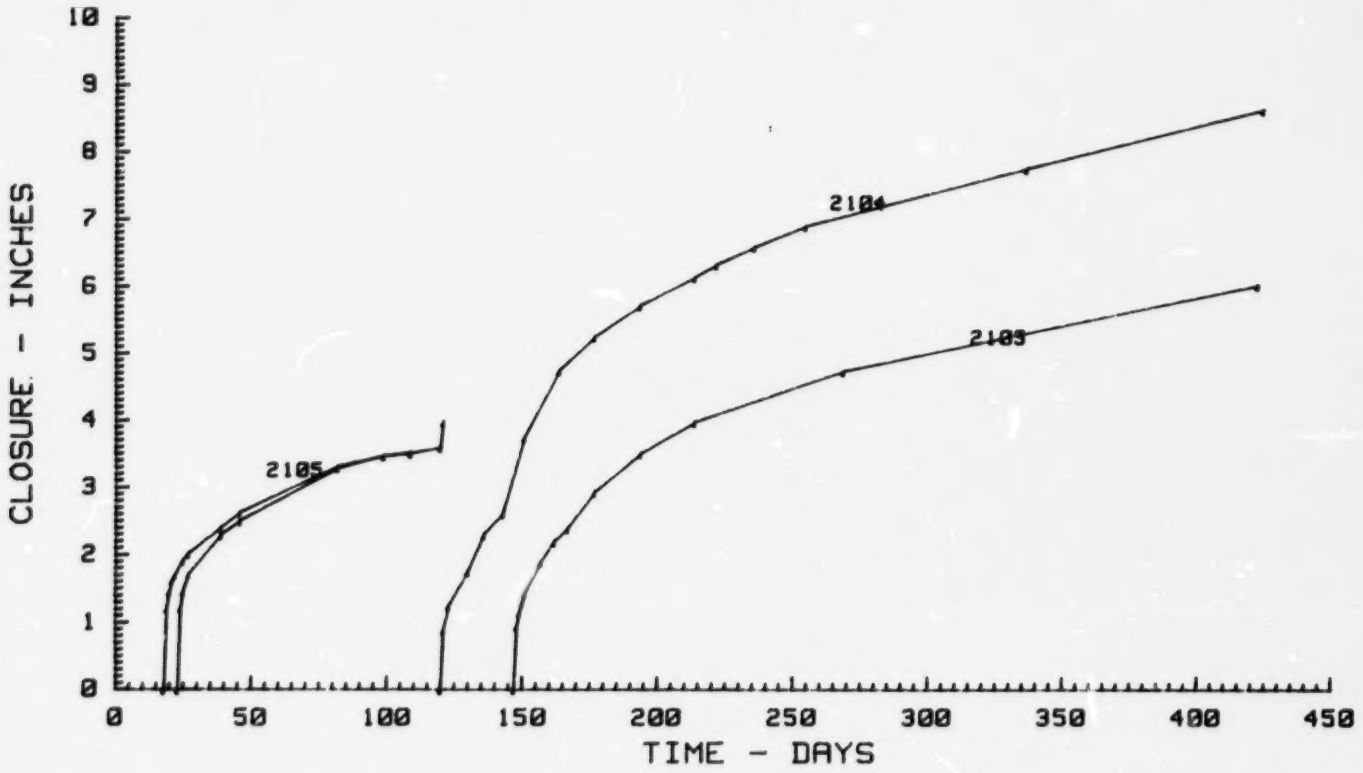
1000 Micro-inches/Hr. = .6mm/Day
1000 Micro-inches/Hr./Ft. = .019mm/cm/Day
= 1.99mm/M./Day

1000 PSI. = 6.894 MPa
1 PSI. = 6.894 KPa



DATE CUT:	FEB.17/84	MAY 12/84	JUNE 4/84	APR.30/84	JAN.23/84

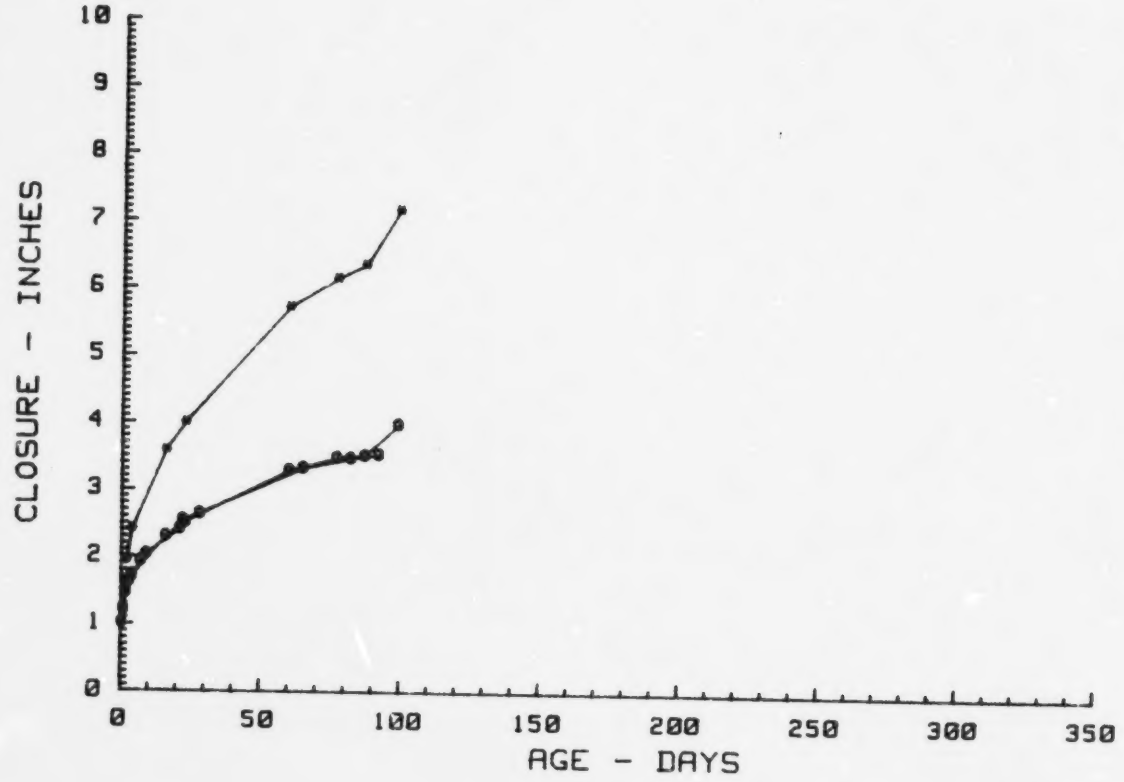
FIGURE 1



CLOSURE VS. REAL TIME

DAY 1 = JAN. 1/1984

FIGURE 2

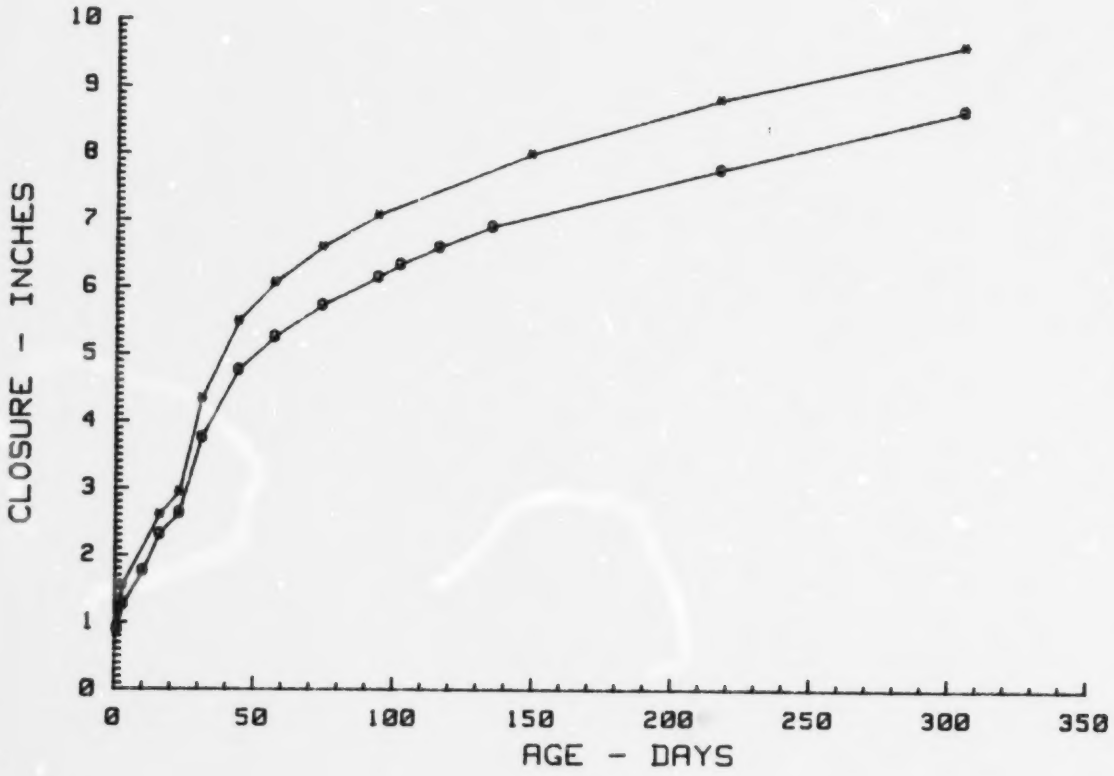


2105 TOTAL VERTICAL CLOSURE

* - CENTRE-LINE SITE

O - RIB SITE

FIGURE 3

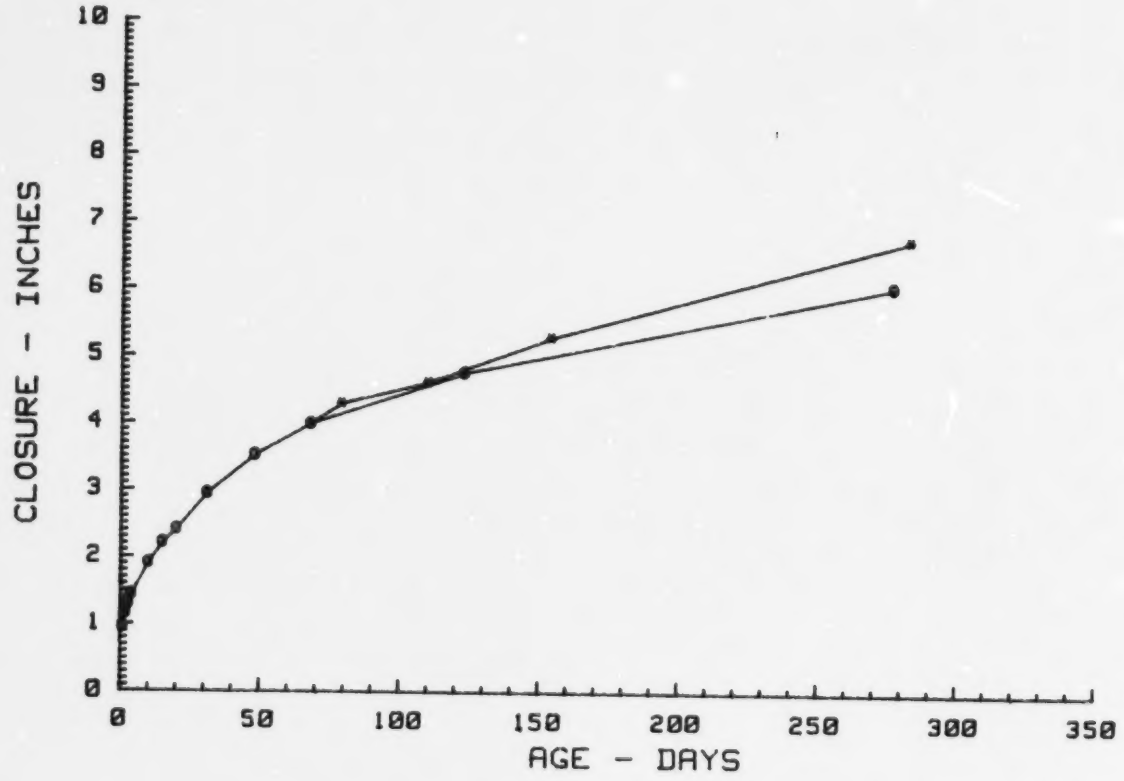


2104 TOTAL VERTICAL CLOSURE

* - CENTRE-LINE SITE

O - RIB SITE

FIGURE 4

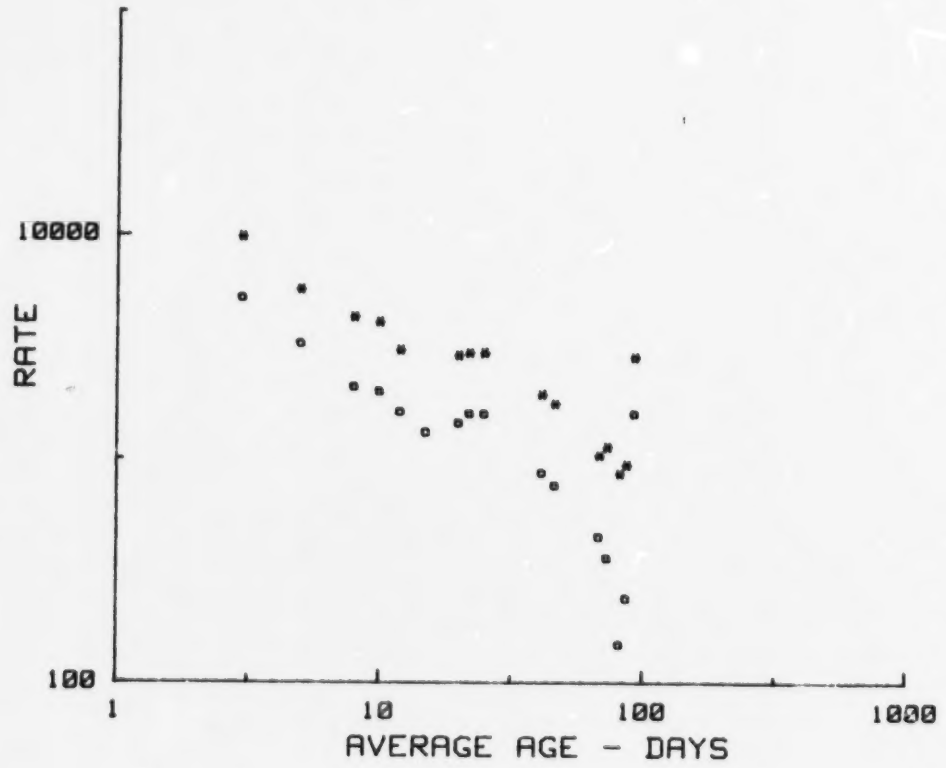


2103 TOTAL VERTICAL CLOSURE

* - CENTRE-LINE SITE

O - RIB SITE

FIGURE 5



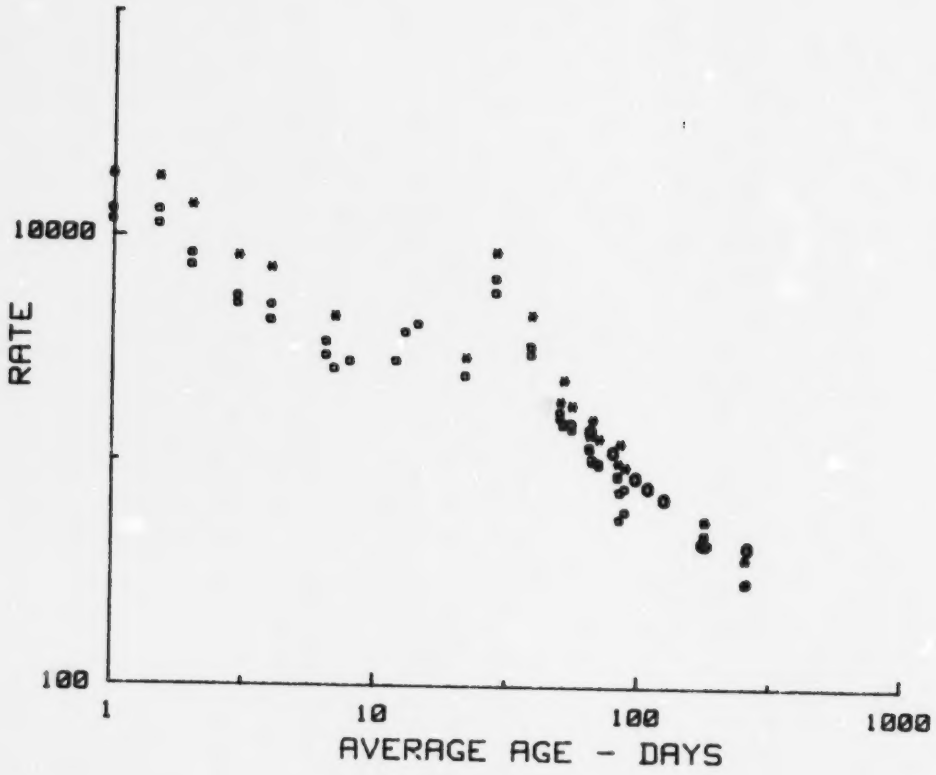
2105 VERTICAL CLOSURE RATE

(MICRO-INCHES/HR.)

o - RIB SITE

* - CENTRE-LINE SITE

FIGURE 6



2104 VERTICAL CLOSURE RATE

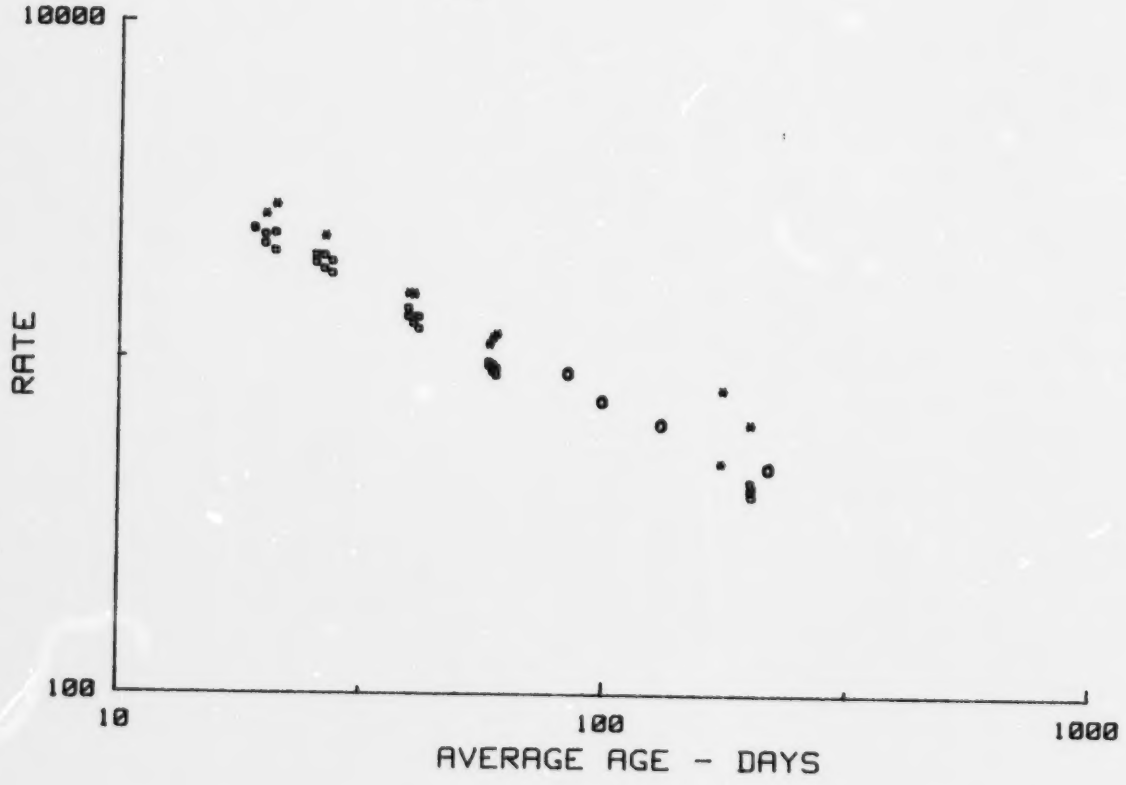
(MICRO-INCHES/HR.)

o - RIB SITE

* - CENTRE-LINE SITE

O - PROJECT SITE

FIGURE 7



2103 VERTICAL CLOSURE RATE

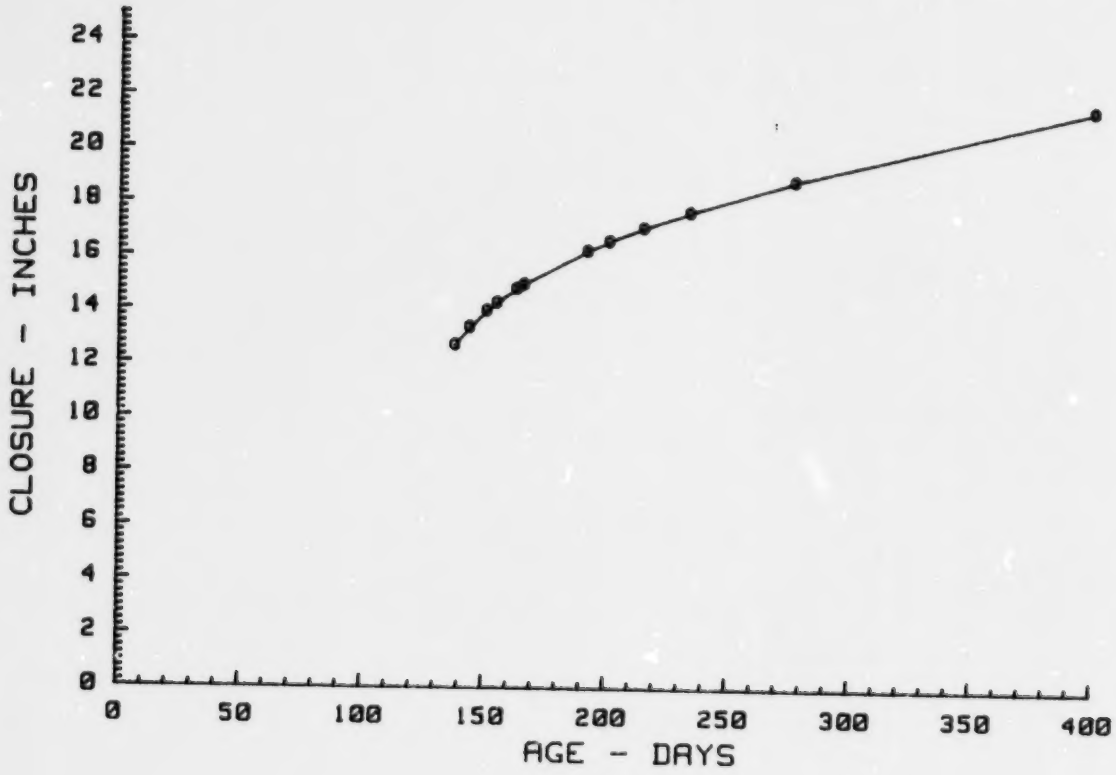
(MICRO-INCHES/HR.)

o - RIB SITE

* - CENTRE-LINE SITE

O - PROJECT SITE

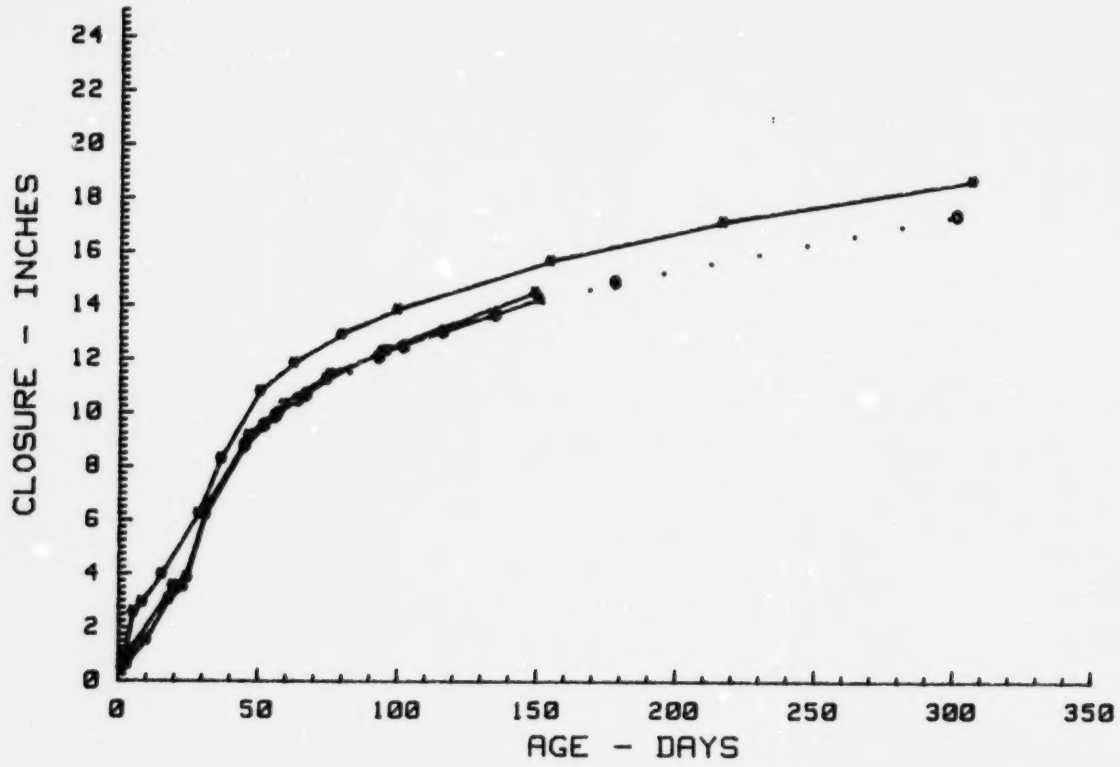
FIGURE 8



2105 TOTAL HORIZONTAL CLOSURE

PROJECT SITE

FIGURE 9

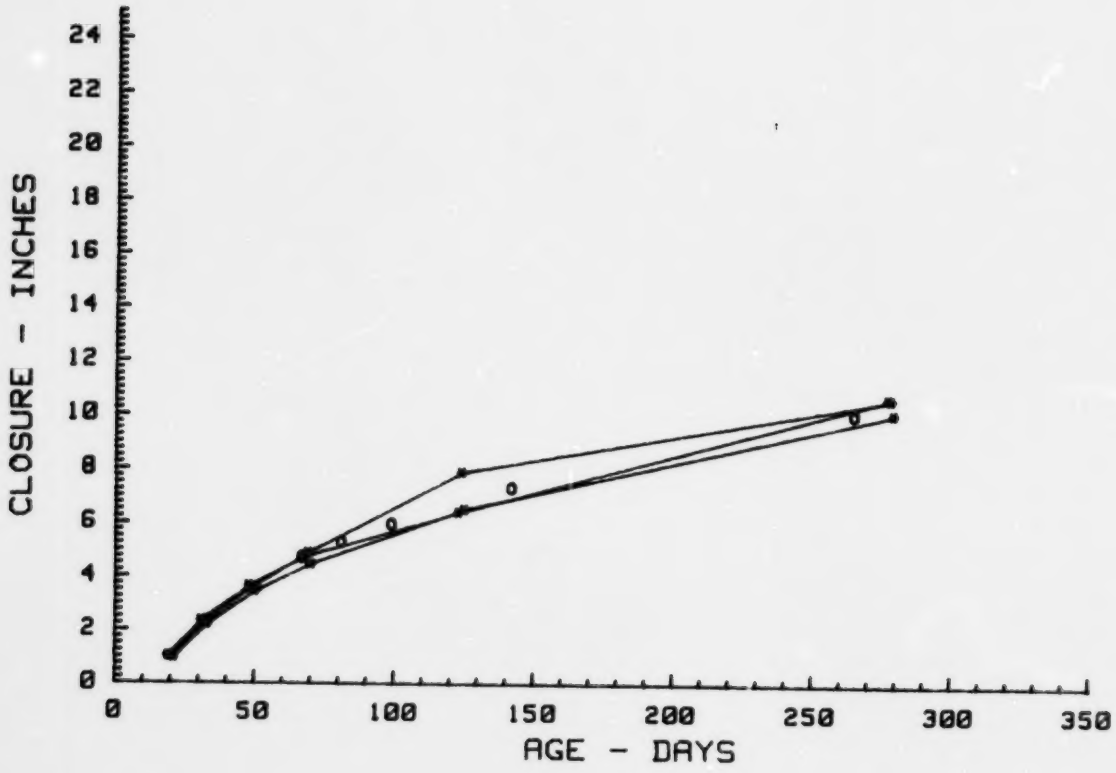


2104 TOTAL HORIZONTAL CLOSURE

* - 300-500-700M SITES

O - PROJECT SITE

FIGURE 10

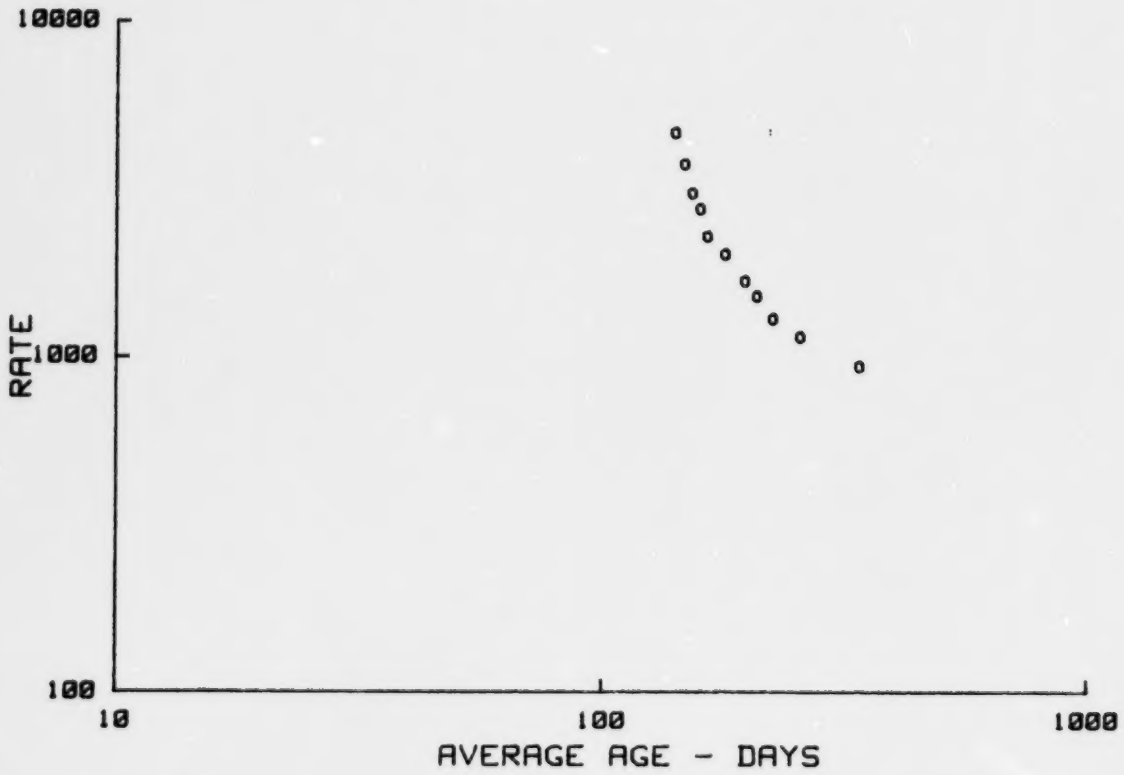


2103 TOTAL HORIZONTAL CLOSURE

* - 300-500-700M SITES

O - PROJECT SITE

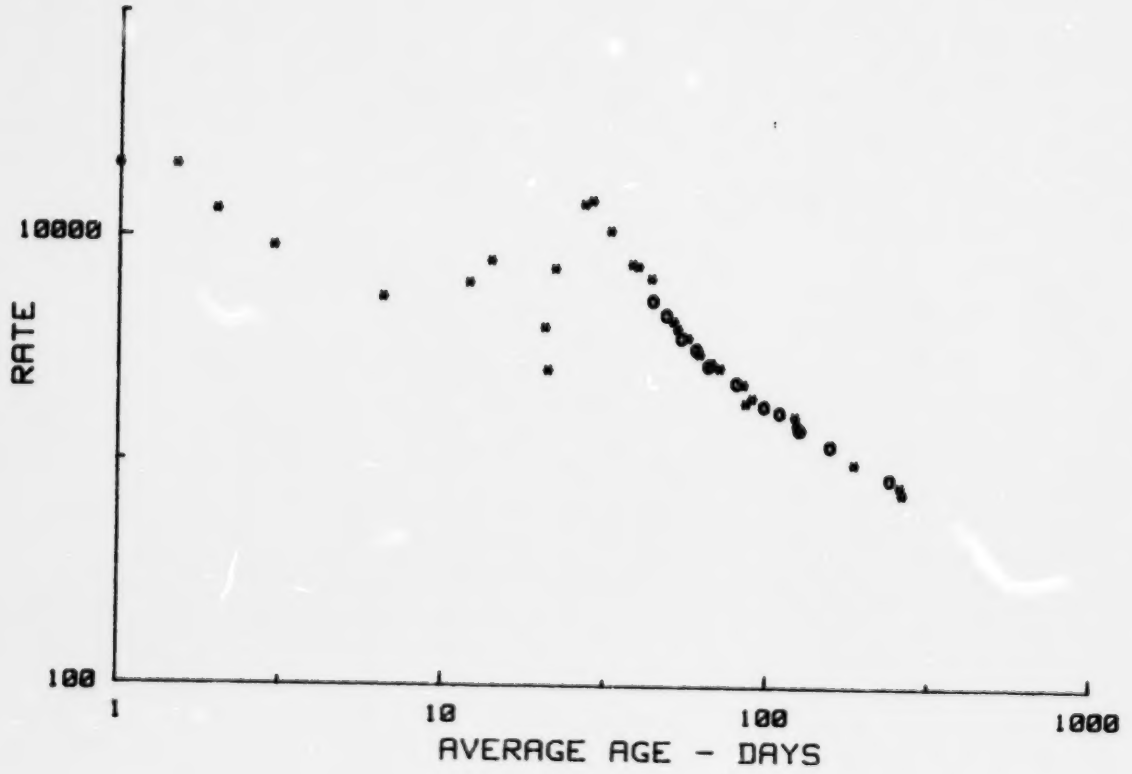
FIGURE 11



2105 HORIZONTAL CLOSURE RATE
(MICRO-INCHES/HR.)

PROJECT SITE

FIGURE 12

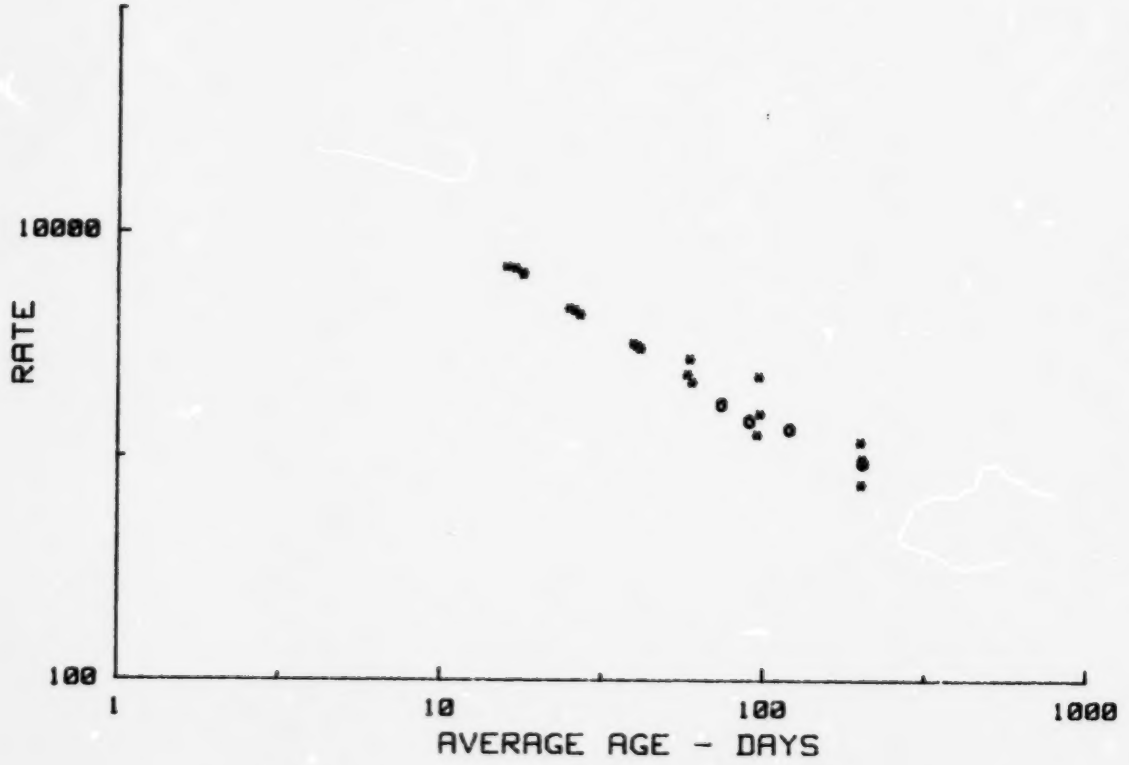


2104 HORIZONTAL CLOSURE RATE
(MICRO-INCHES/HR.)

* - 300-500-700M SITES

O - PROJECT SITE

FIGURE 13

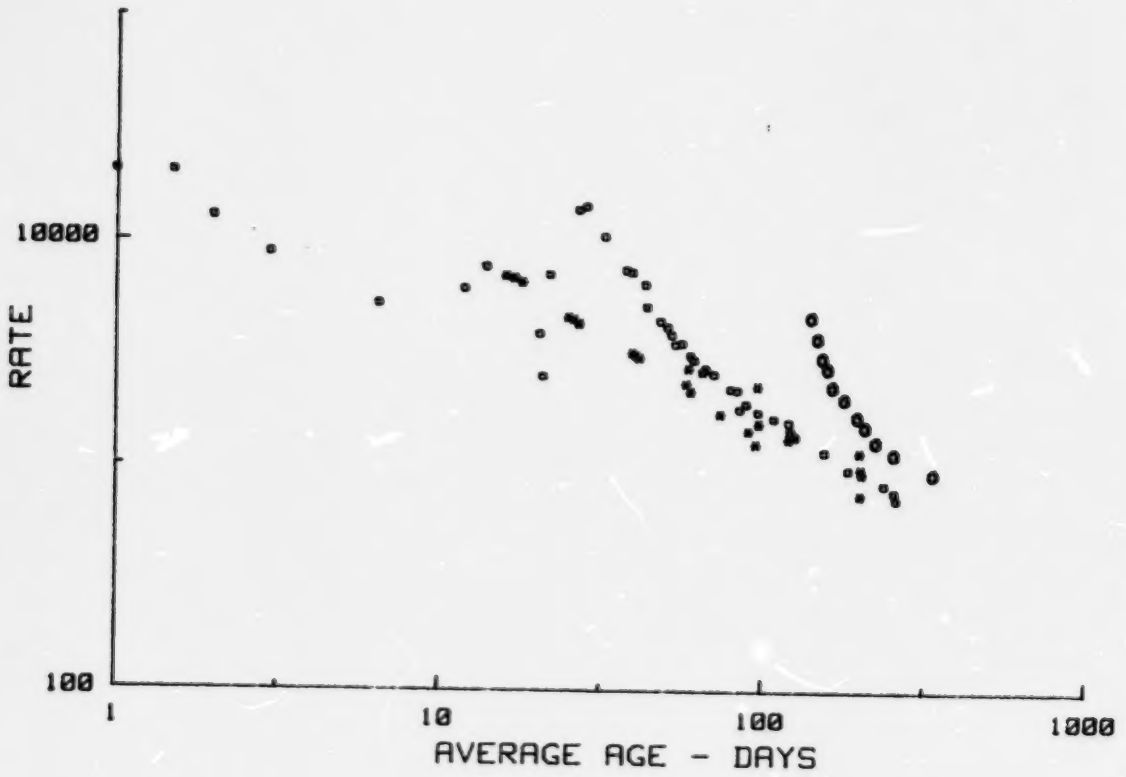


2103 HORIZONTAL CLOSURE RATE
(MICRO-INCHES/HR.)

* - 500-600-700M SITES

O - PROJECT SITE

FIGURE 14



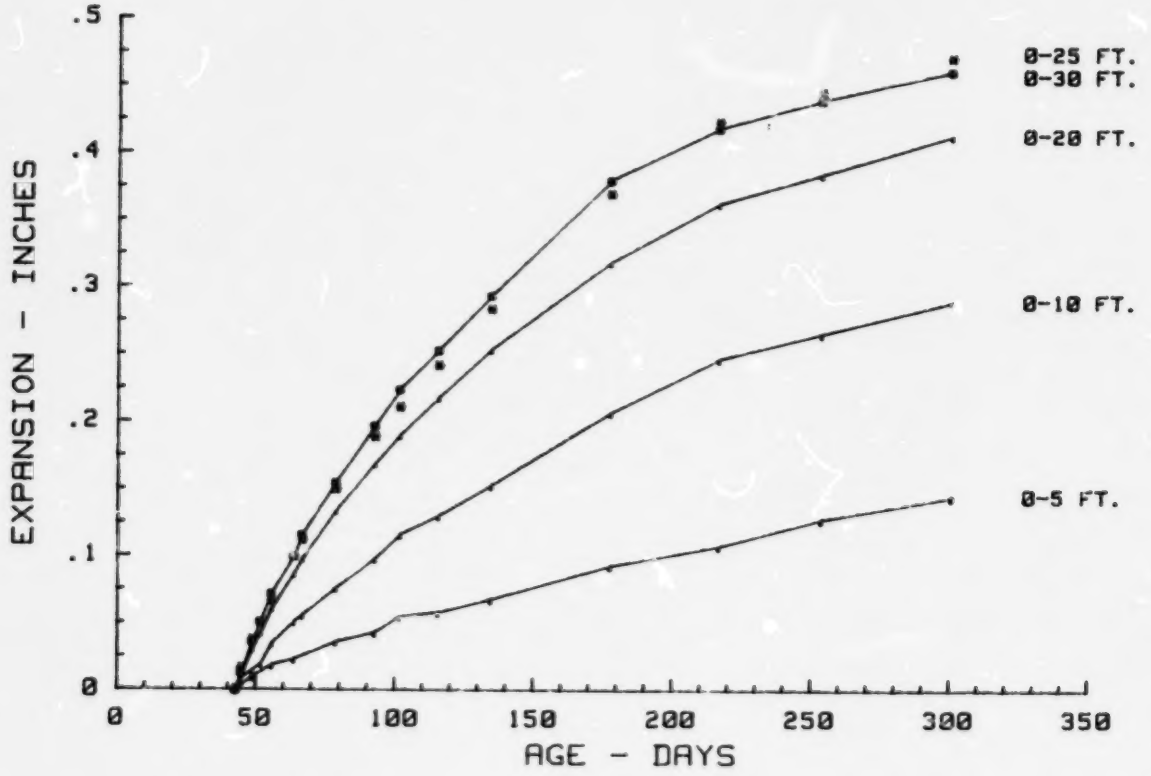
HORIZONTAL CLOSURE RATE COMPARISON
(MICRO-INCHES/HR.)

* - 2103

o - 2104

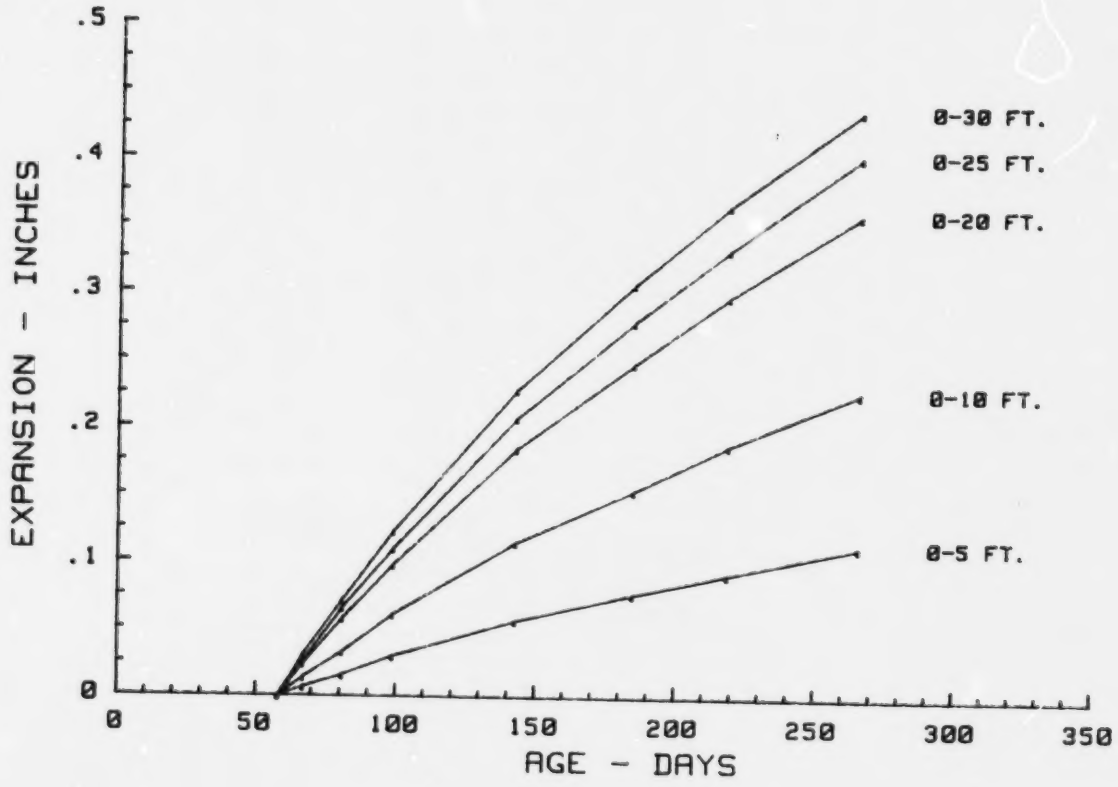
O - 2105

FIGURE 15



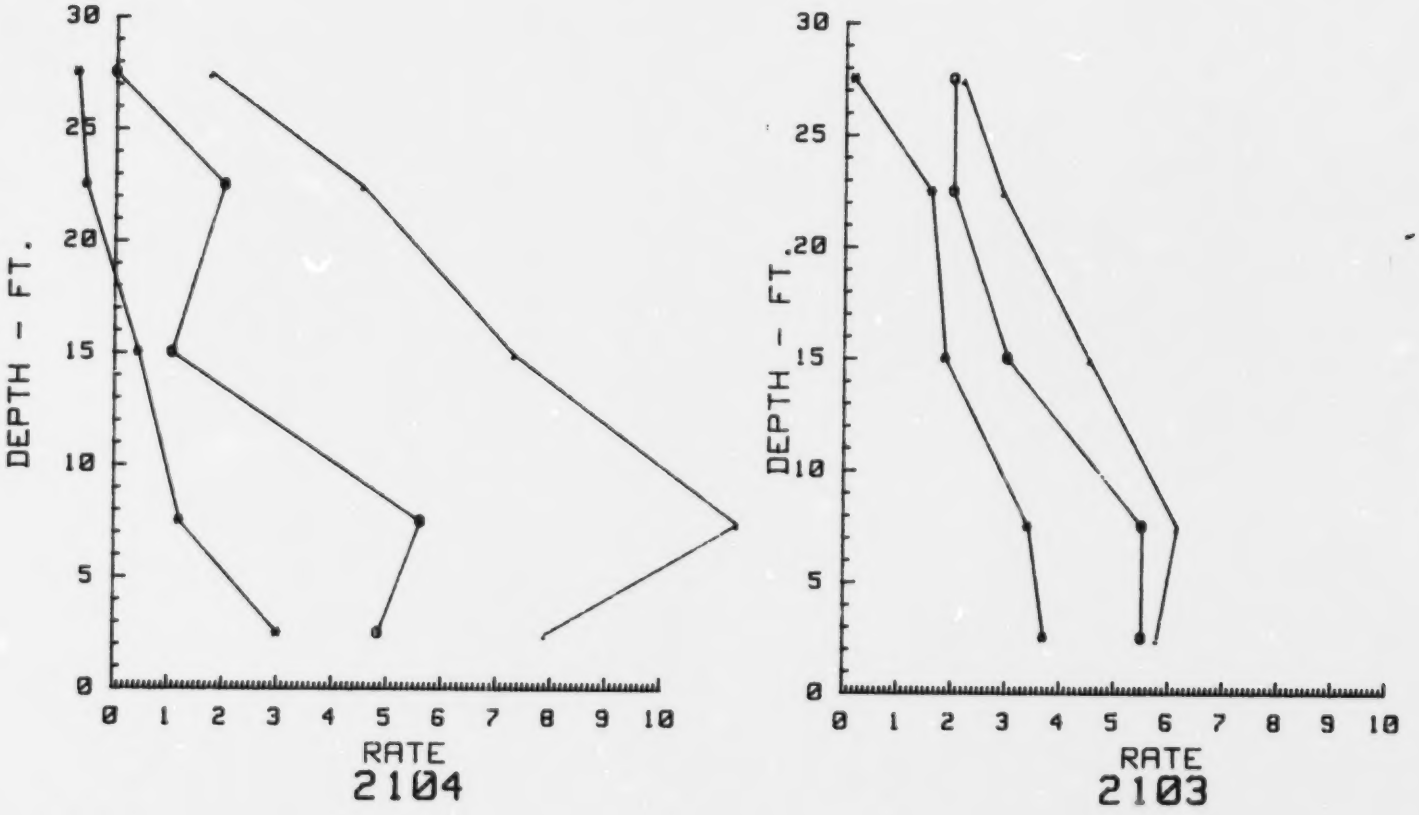
2104 BACK EXPANSION

FIGURE 16



2103 BACK EXPANSION

FIGURE 17



BACK CREEP RATE DISTRIBUTION

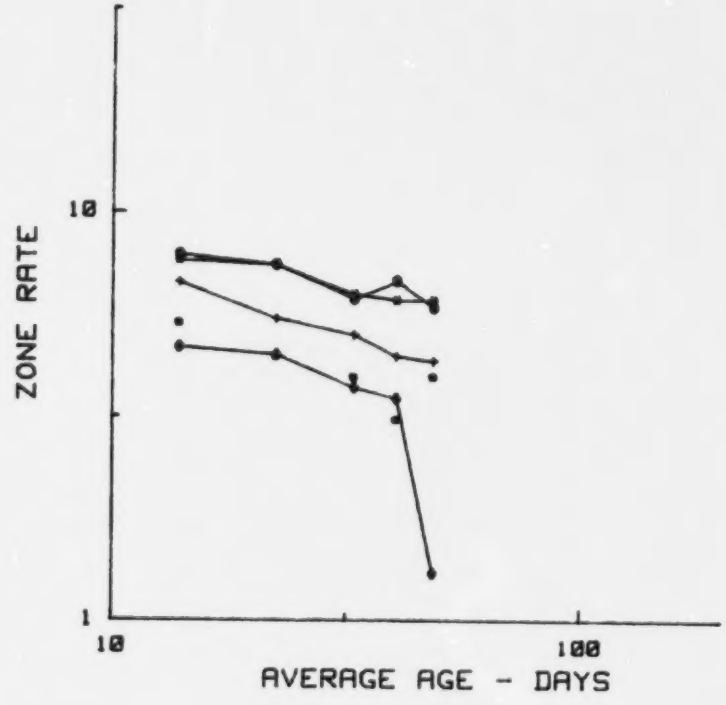
(MICRO-INCHES/HR./FT.)

. JULY/84

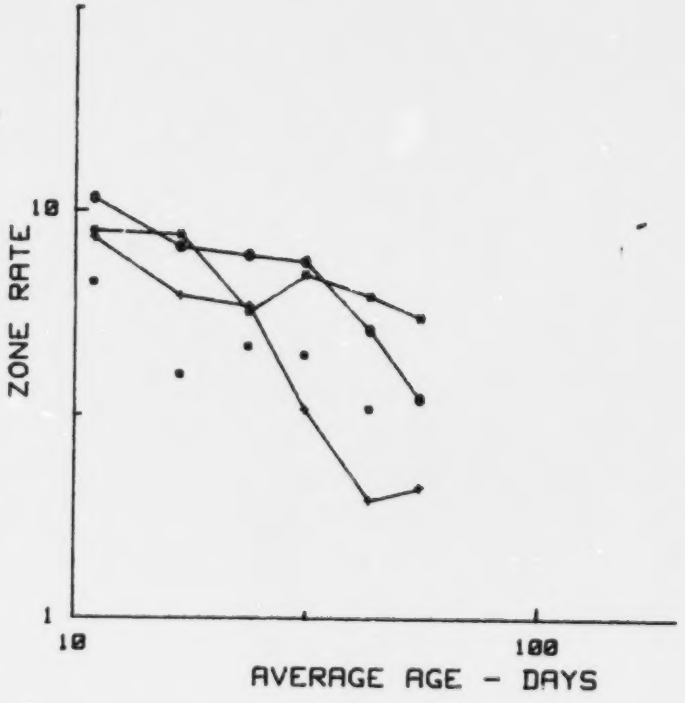
O OCT./84

* FEB./85

FIGURE 18



2103

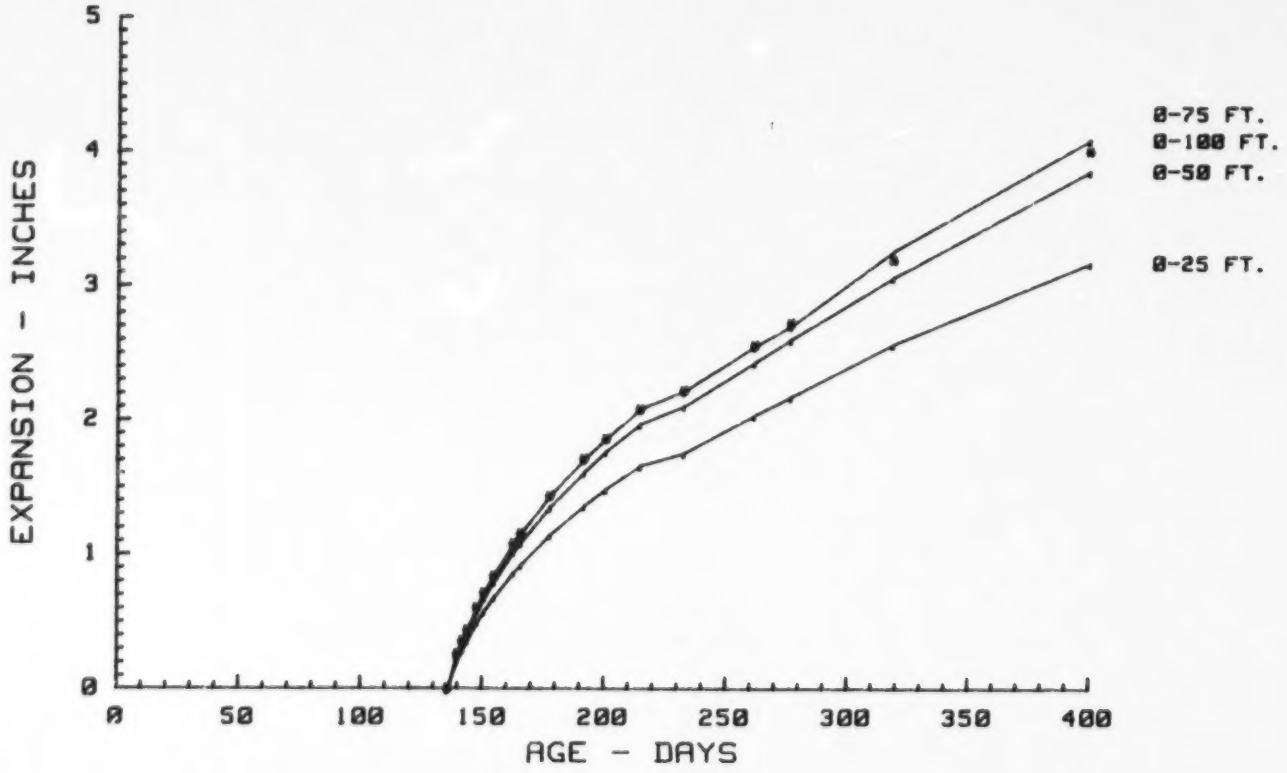


2104

BACK ZONE RATE COMPARISON
(MICRO-INCHES/HR./FT.)

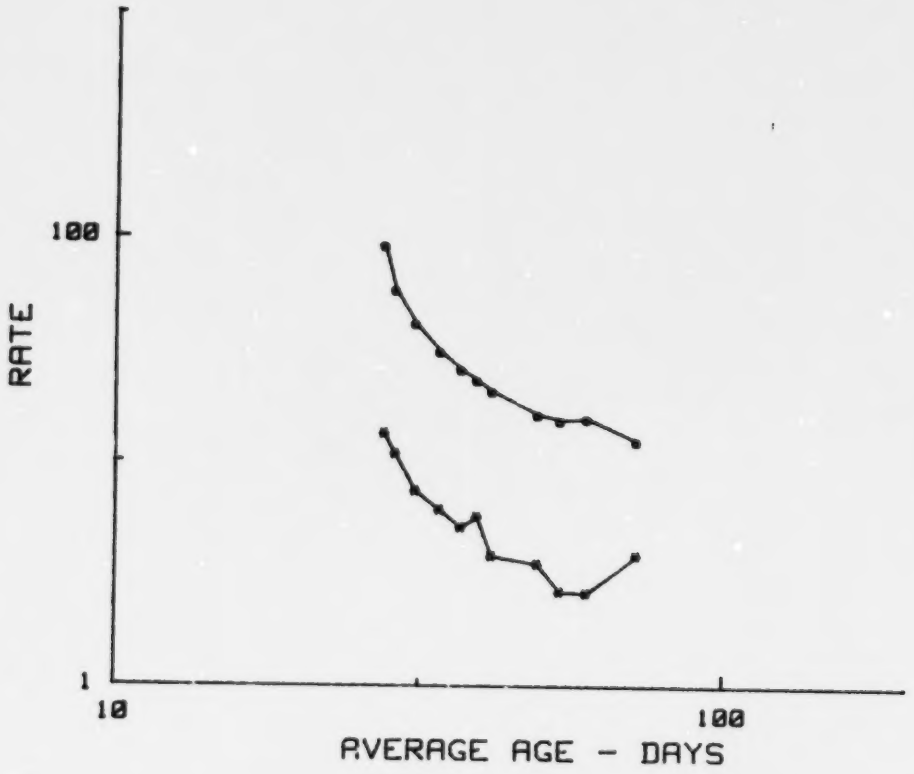
* 0-5 FT.
O 5-10 FT.
\+ 10-20 FT.
o 20-25 FT.
* 25-30 FT.

FIGURE 19



2105 TOTAL WALL EXPANSION
(EAST WALL)

FIGURE 20

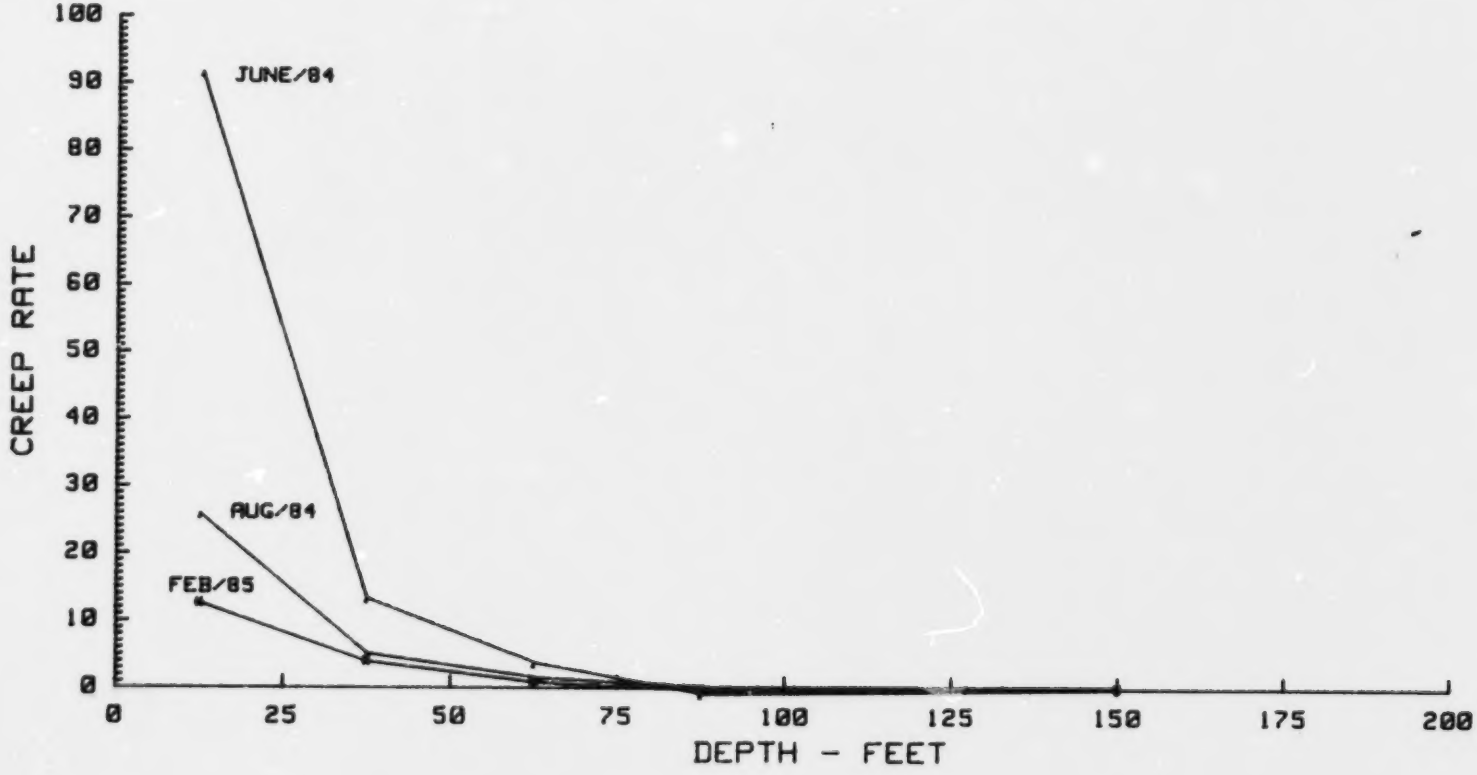


2105 WALL CREEP RATE
(MICRO-INCHES/HR./FT.)

o 0-25FT.

* 25-50FT.

FIGURE 21

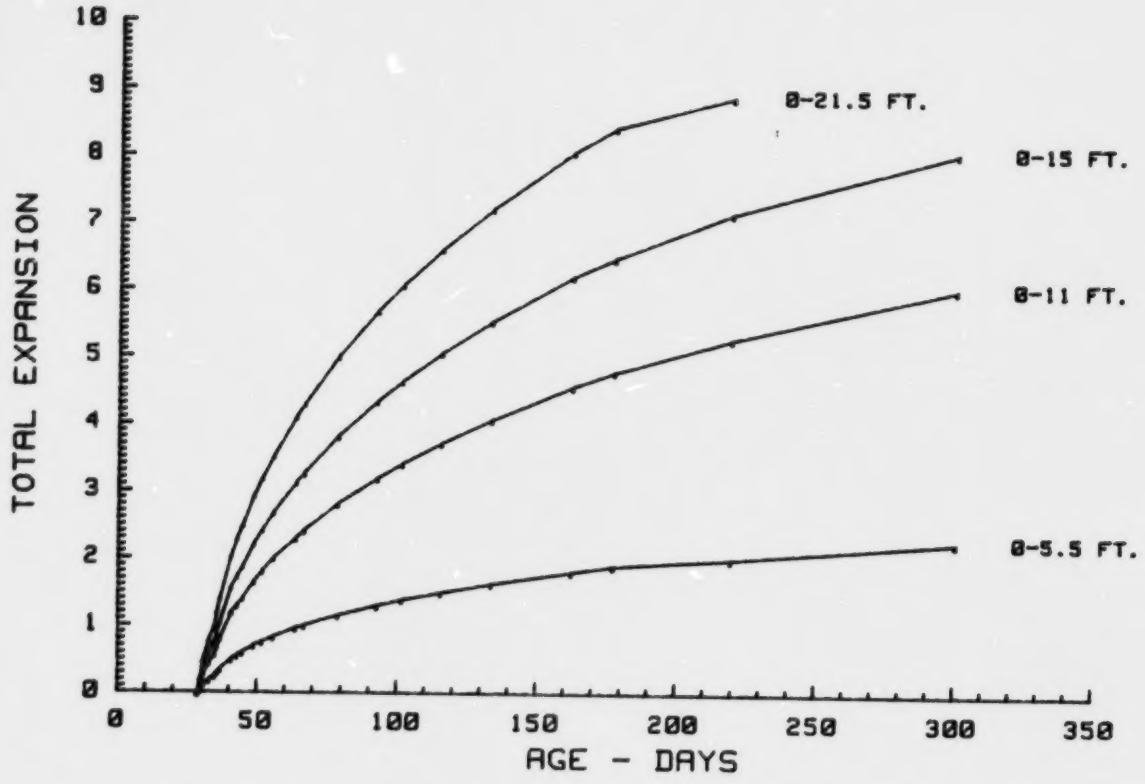


2105 CREEP RATE DISTRIBUTION

(MICRO-INCHES/HR./FT.)

EAST WALL

FIGURE 22



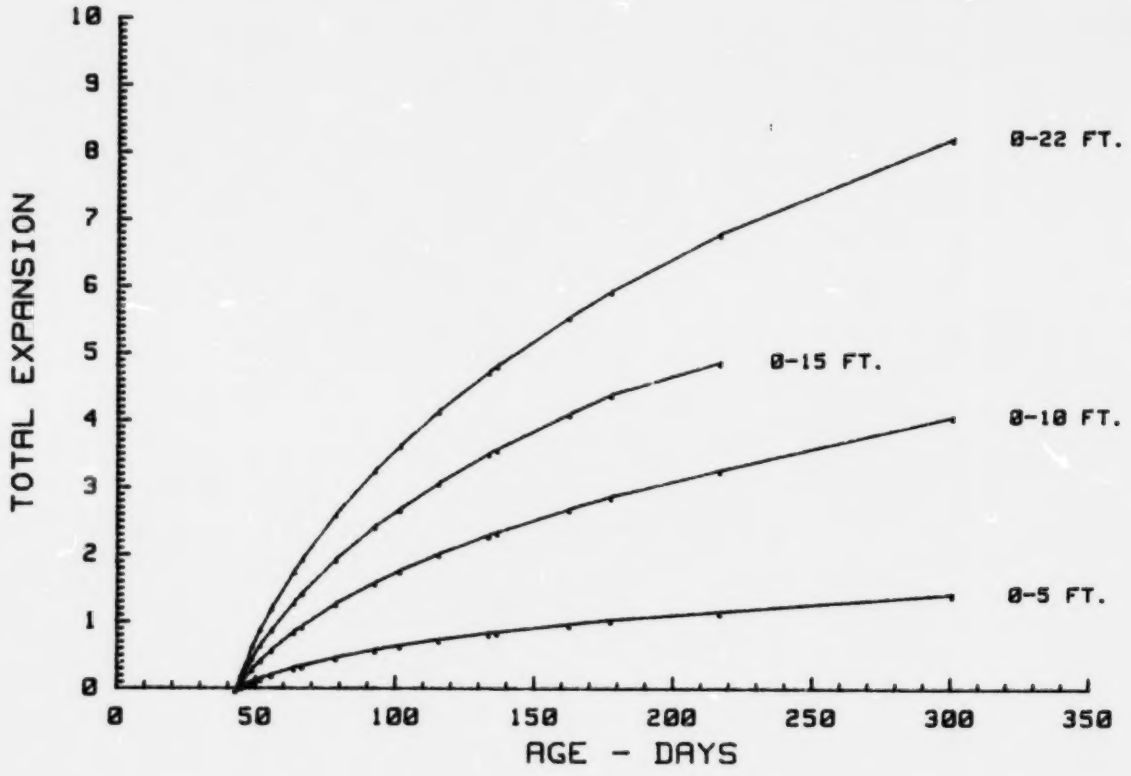
2104 EAST YIELD PILLAR

TOTAL EXPANSION - INCHES

PILLAR WIDTH - 21.5 FT.

SITE No. 1

FIGURE 23



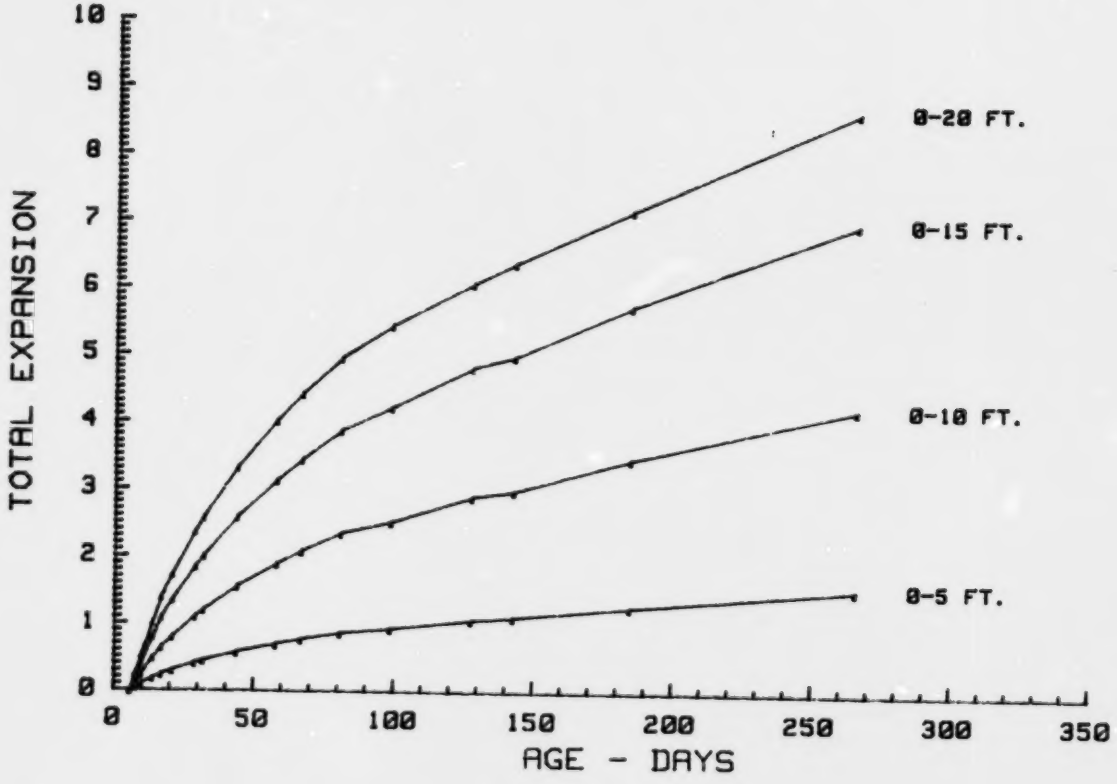
2104 EAST YIELD PILLAR

TOTAL EXPANSION - INCHES

PILLAR WIDTH - 22 FT.

SITE No.2

FIGURE 24

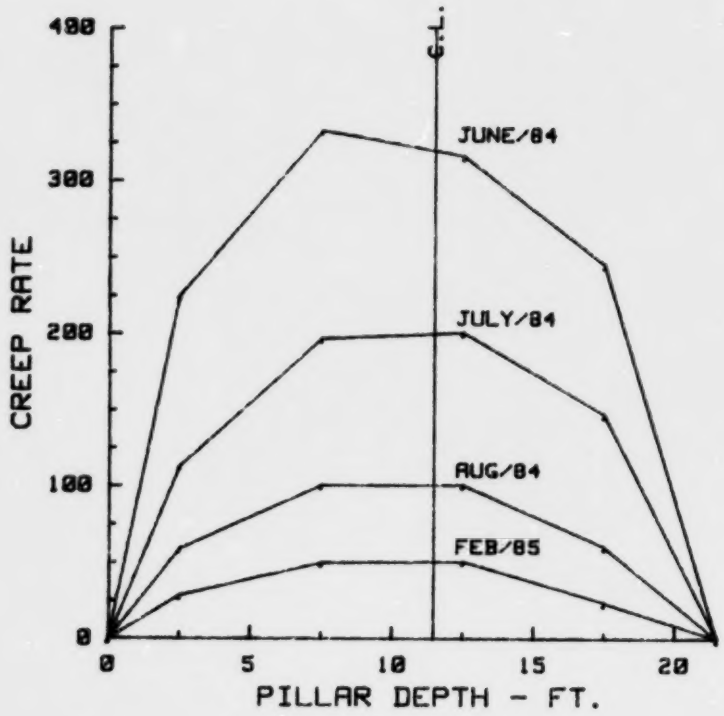


2104 WEST YIELD PILLAR

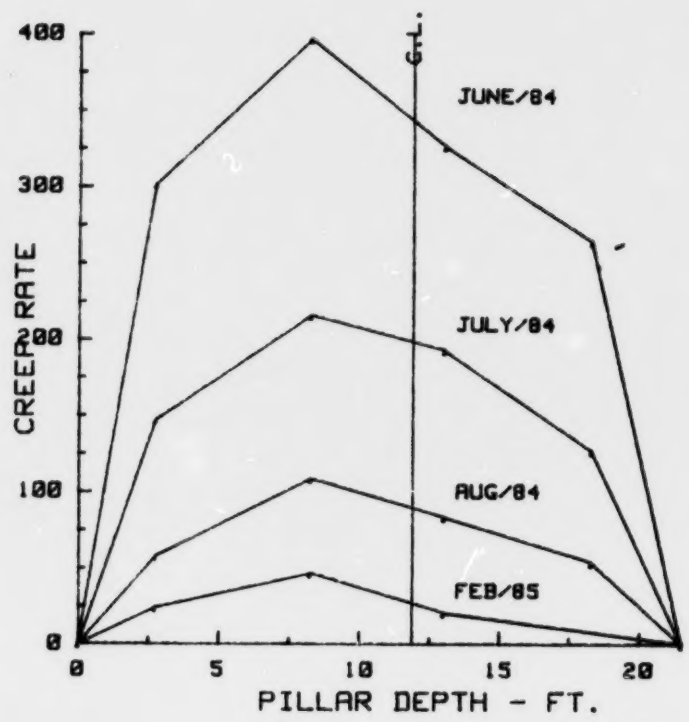
TOTAL EXPANSION - INCHES

PILLAR WIDTH - 21.5 FT.

FIGURE 25



WEST PILLAR

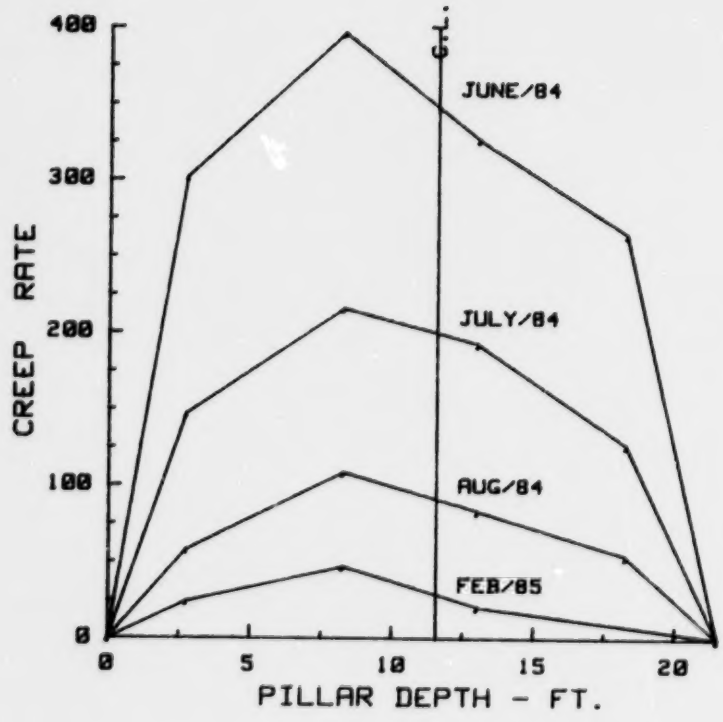


EAST PILLAR

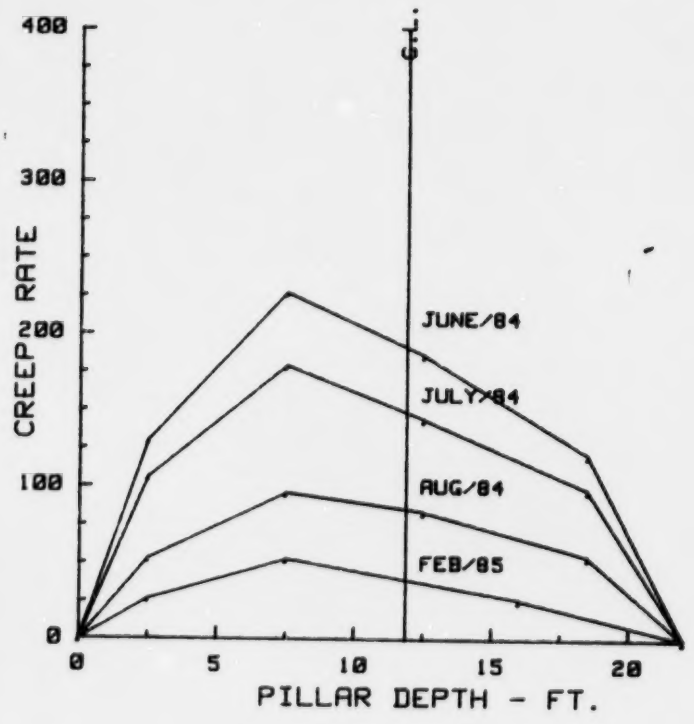
2104 YIELD PILLAR COMPARISON

(CREEP RATE - MICRO-INCHES/HR./FT.)

FIGURE 2E



SITE 1

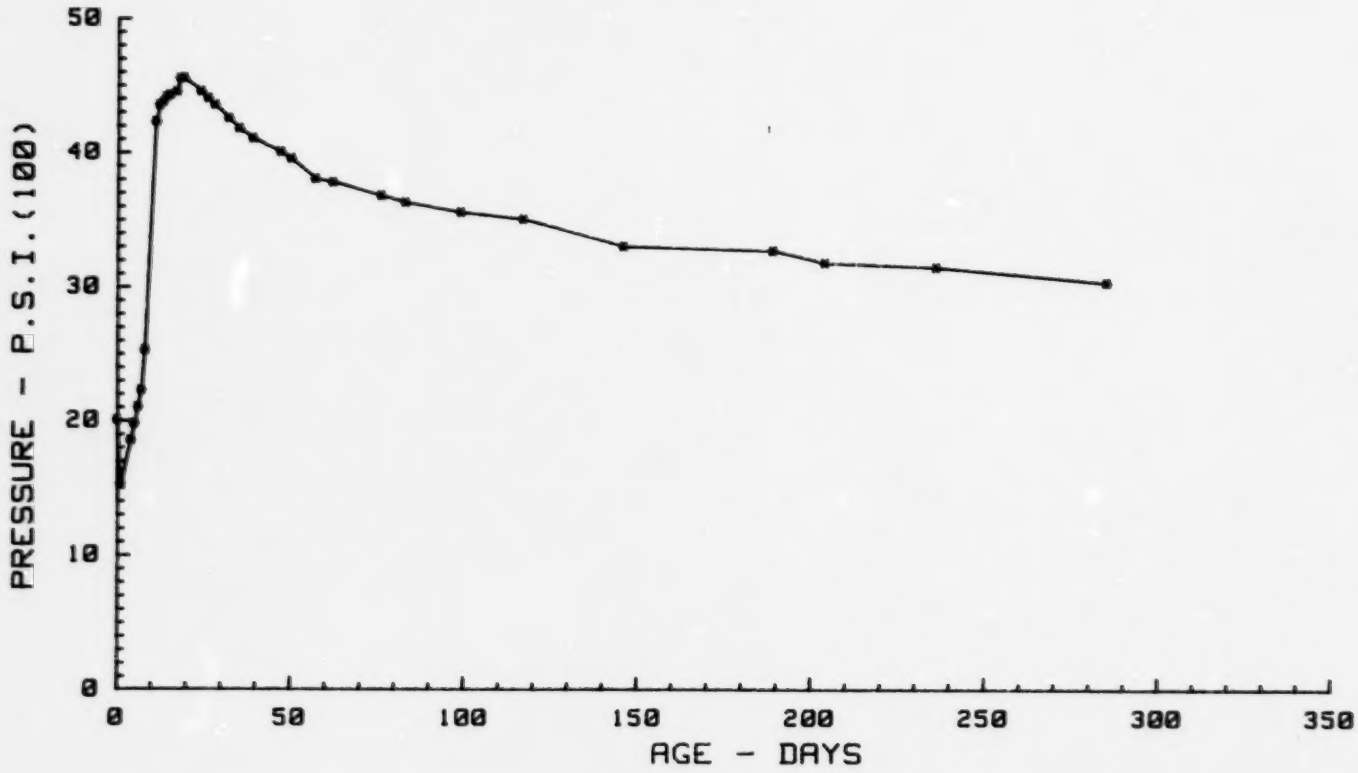


SITE 2

SITE COMPARISON 2104 EAST PILLAR

(CREEP RATE - MICRO-INCHES/HR./FT.)

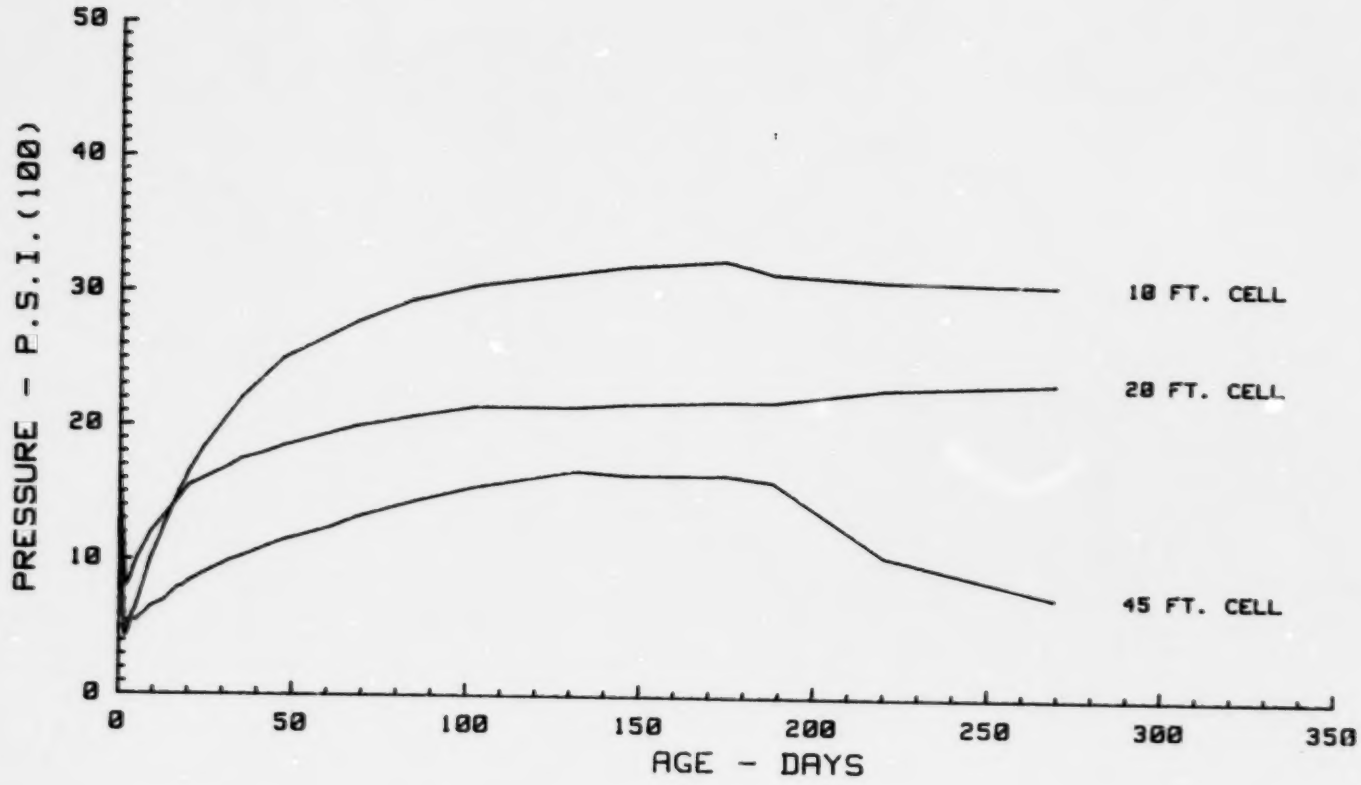
FIGURE 27



2104 - 2105 YIELD PILLAR

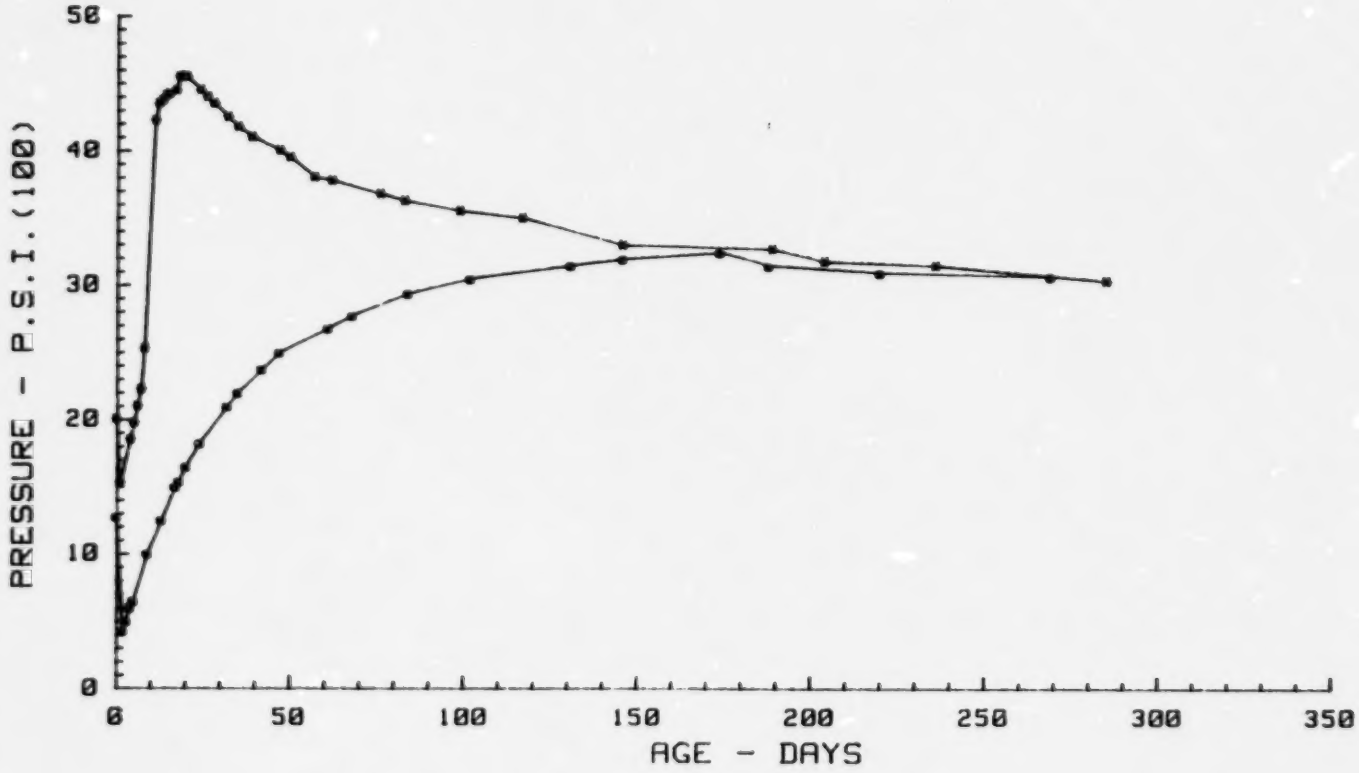
DEPTH - 12.5 FT. FROM 2105

FIGURE 28



2105 EAST WALL

FIGURE 29

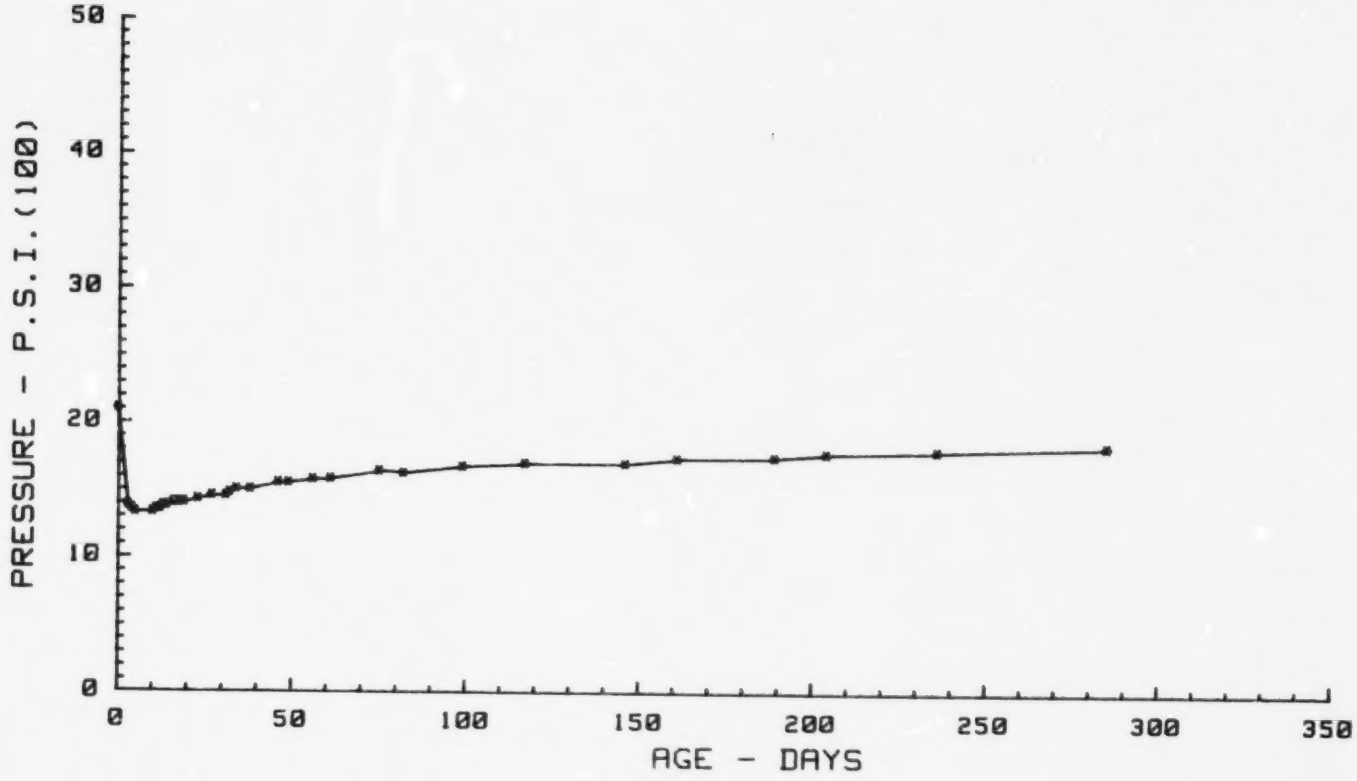


CELL COMPARISON

* 2104 - 2105 YIELD PILLAR

o 2105 EAST WALL - 10 FT. DEPTH

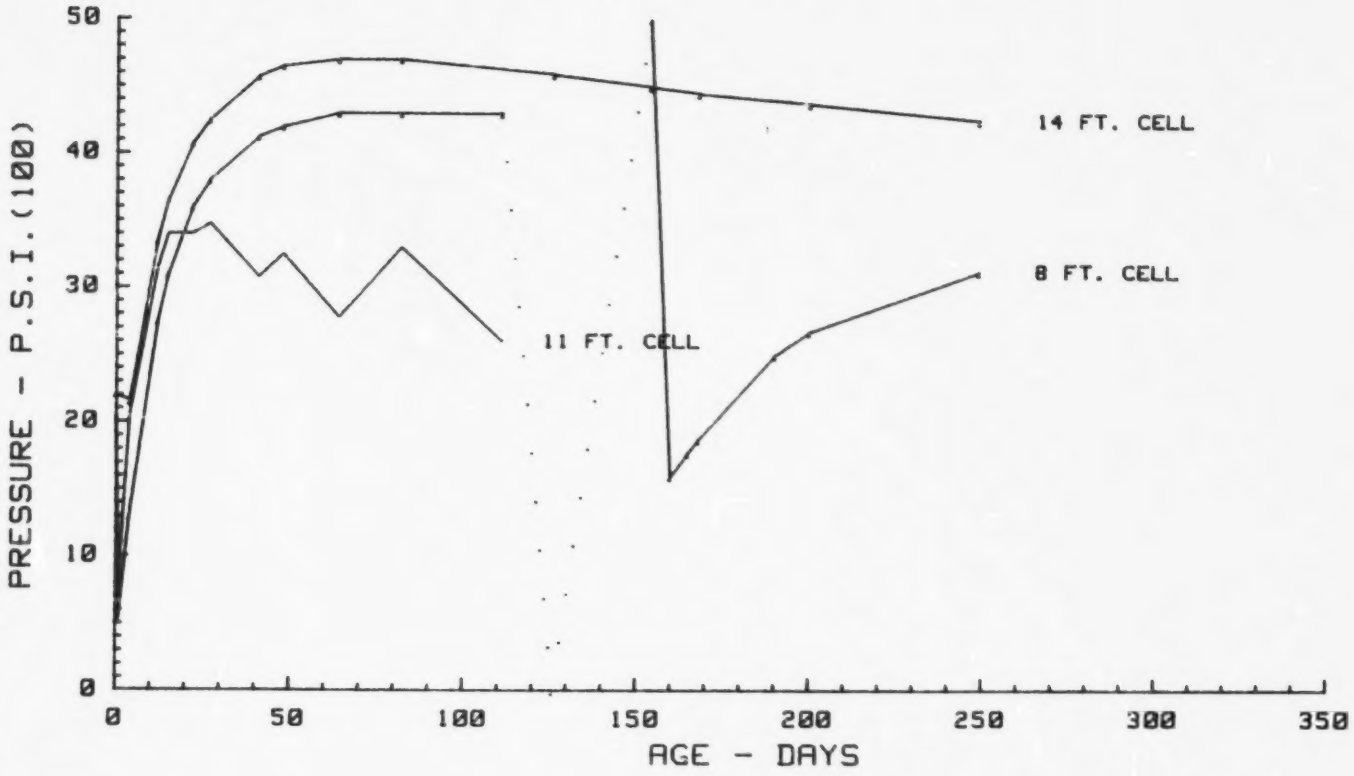
FIGURE 30



2105 FLOOR

DEPTH - 20 FT.

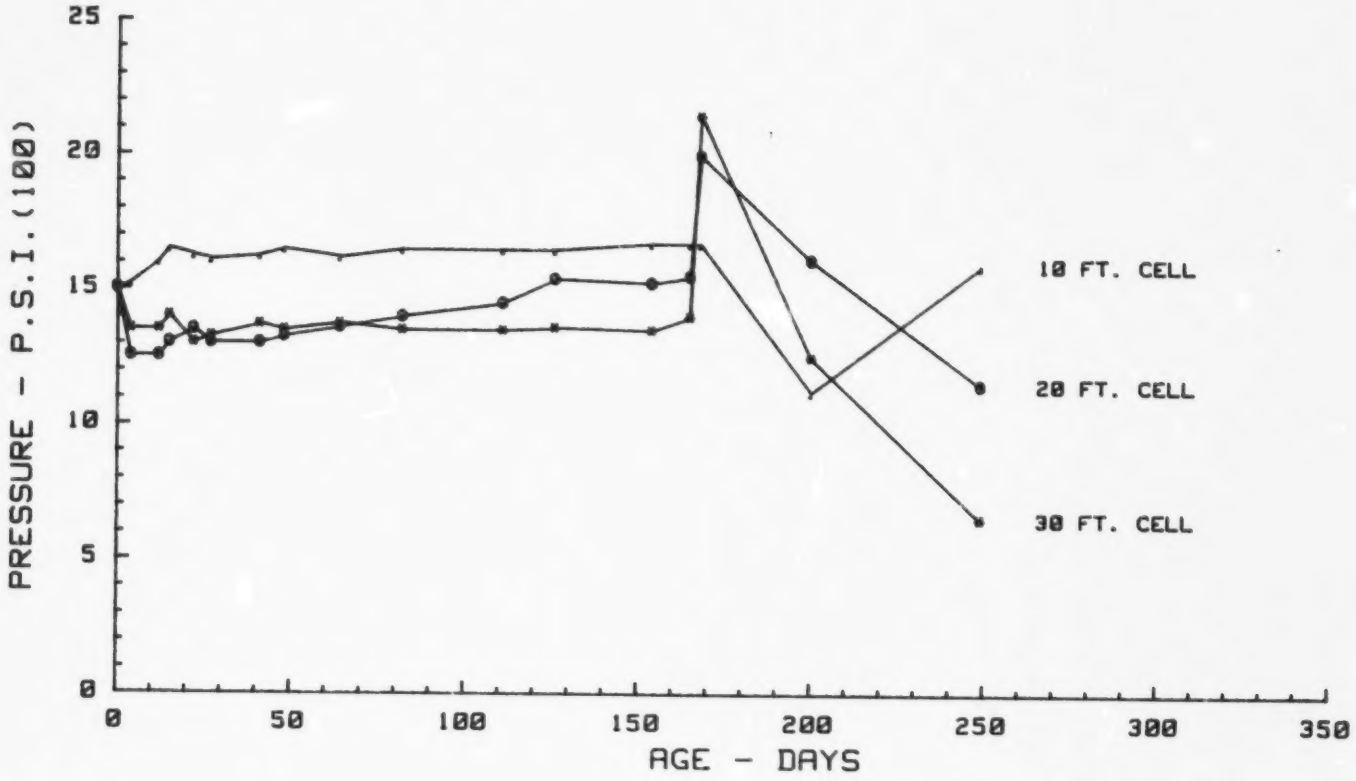
FIGURE 31



2103 - 2104 YIELD PILLAR

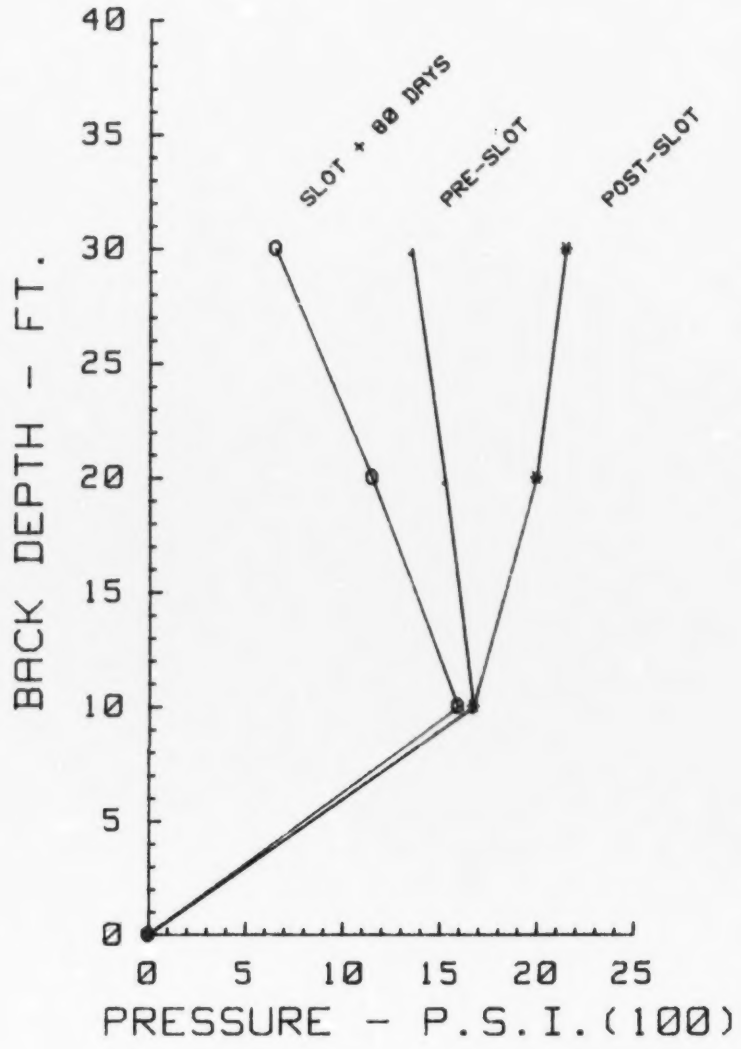
PILLAR WIDTH - 22 FT.

FIGURE 32



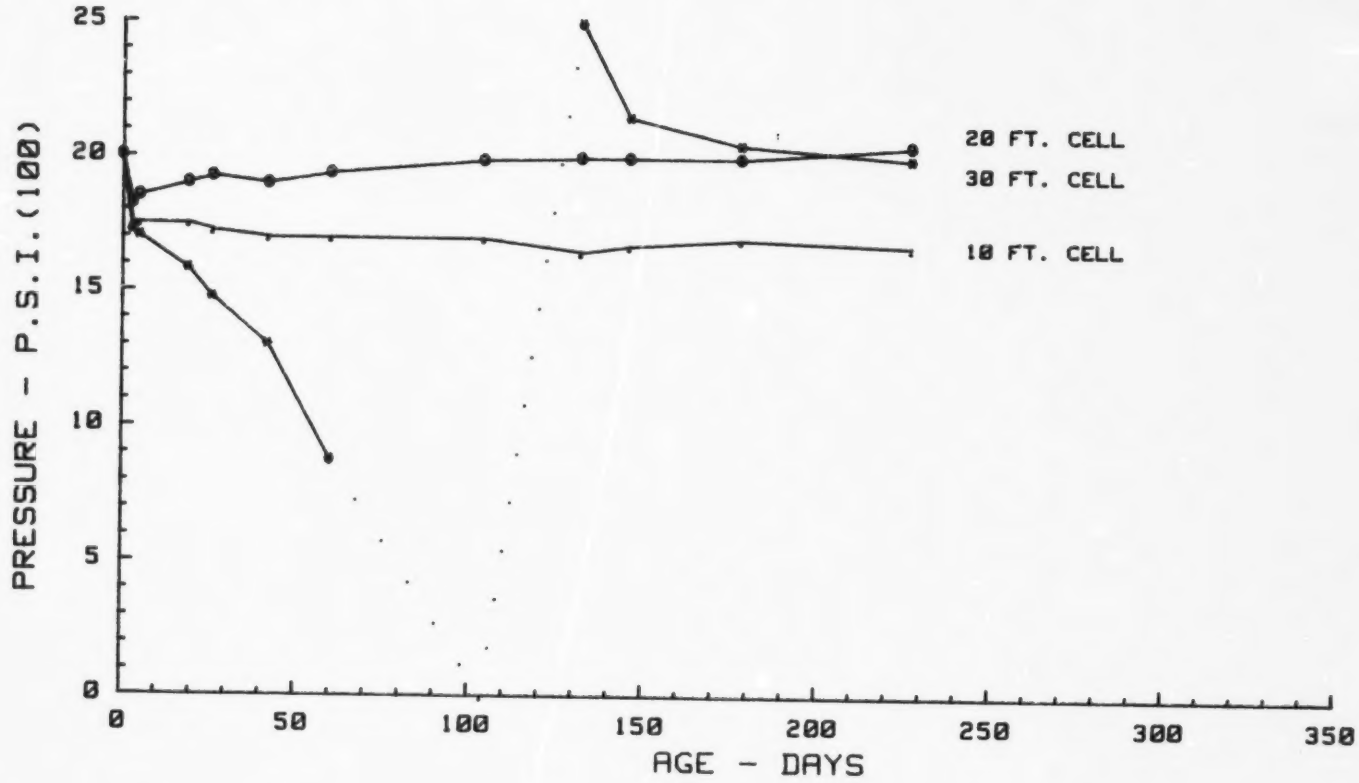
2104 BACK CELLS

FIGURE 33



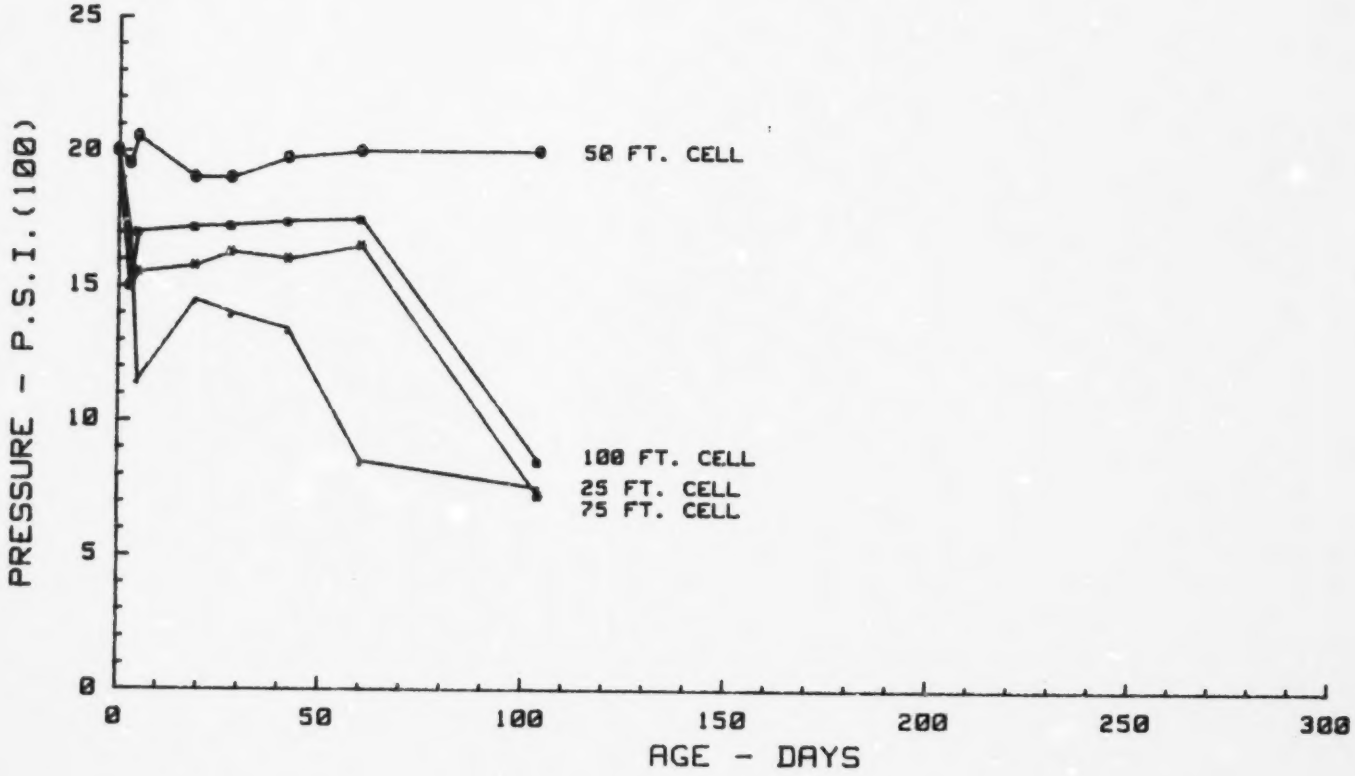
PRESSURE DISTRIBUTION - 2104 BACK

FIGURE 34



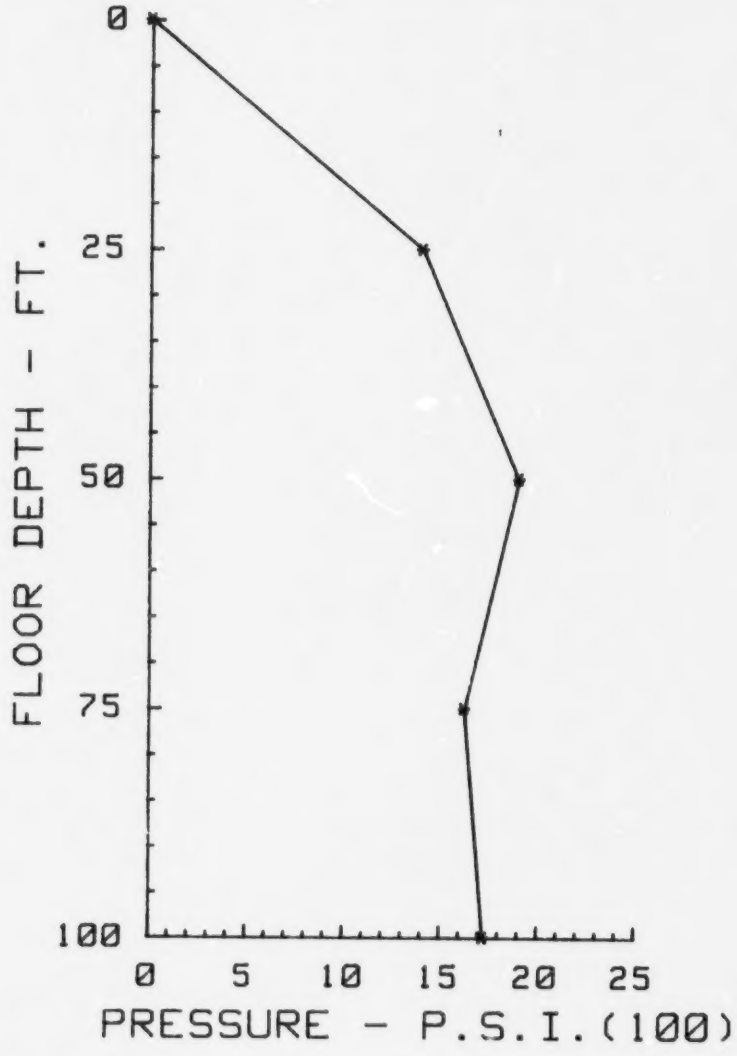
2103 BACK CELLS

FIGURE 35



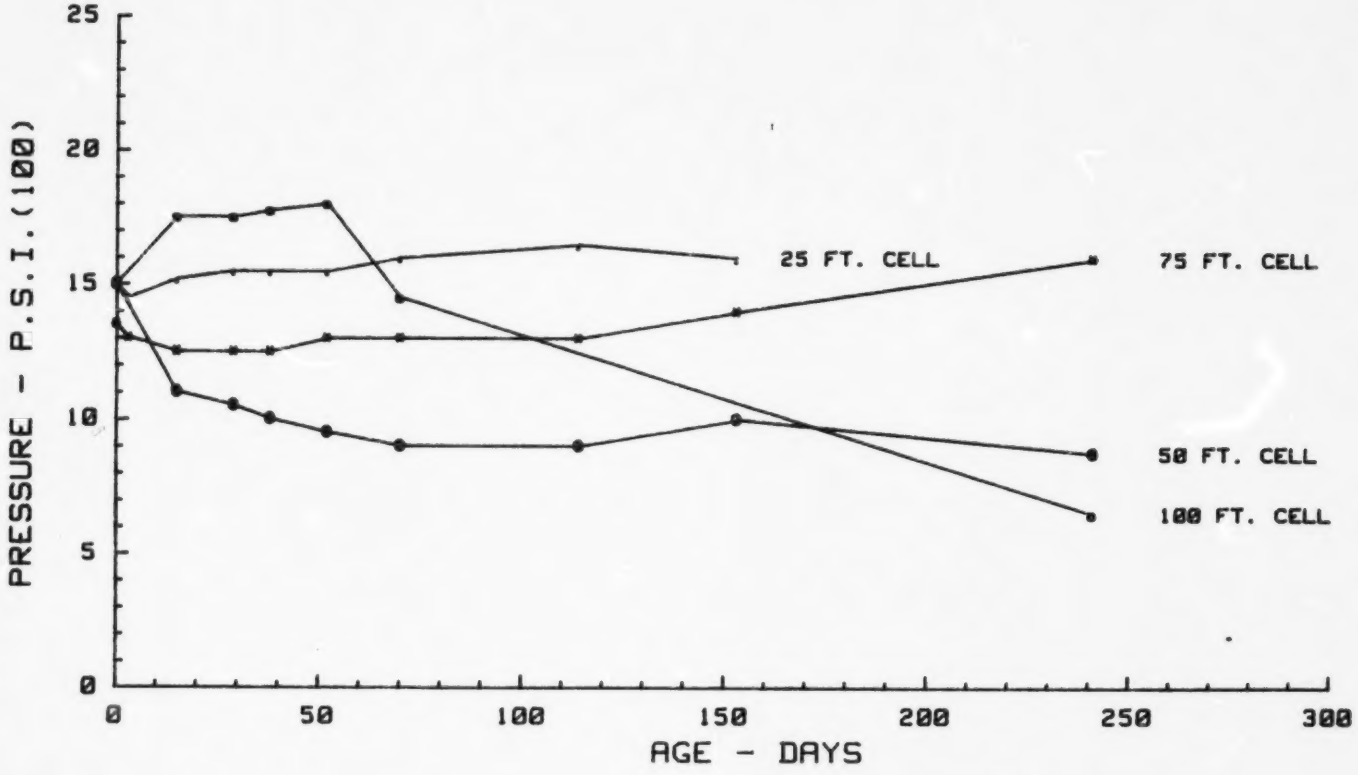
2103 FLOOR CELLS

FIGURE 36



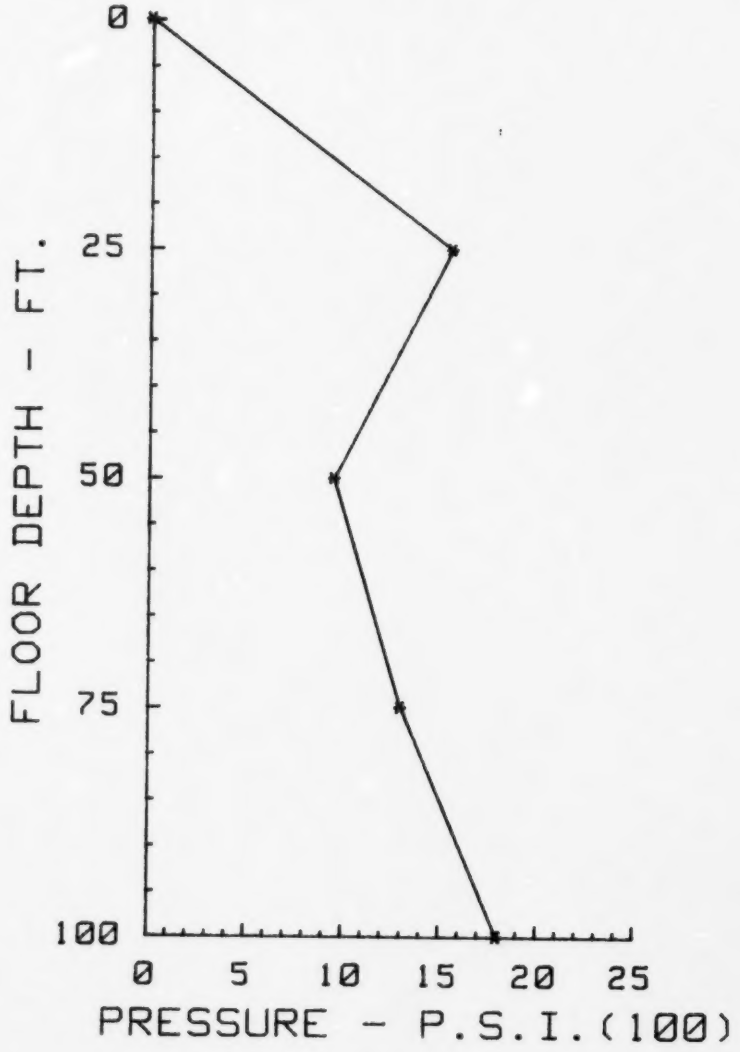
PRESSURE DISTRIBUTION - 2103 FLOOR

FIGURE 37



2104 FLOOR CELLS

FIGURE 38



PRESSURE DISTRIBUTION - 2104 FLOOR

FIGURE 39